BASEMENT-COVER RELATIONSHIPS IN SOUTHEAST NEWFOUNDLAND

PETER A. BROWN

BASEMENT-COVER RELATIONSHIPS

IN SOUTHWEST NEWFOUNDLAND

A Dissertation

Presented to

The Department of Geology

Memorial University of Newfoundland

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

by

© Peter A. Brown

November 1974

ABSTRACT

In the Port aux Basques area five geological divisions are recognised. These are Cape Ray Complex, The Port aux Basques Complex, The Windsor Point Group, The Harbour Le Cou Group and the Bay du Nord Group. The first two are separated by, and the third overlies a 1 km wide mylonite zone the Cape Ray Fault. The Harbour Le Cou and Bay du Nord Groups occur in the eastern part of the area and are deformed during the reworking of the Port aux Basques Complex.

The Cape Ray Complex occurs to the west of the Cape Ray Fault Zone and comprises a chaotic, intensely retrogressed leucocratic gneiss intruded by granitic phases. The Windsor Point Group consists of a series of metasedimentary and metavolcanic rocks which unconformably overlie the Cape Ray Complex and the Cape Ray Fault Zone, and have been mildly deformed by late movements along the fault.

The Port aux Basques Complex crops out to the east of the Cape Ray Fault Zone and comprises a well banded gneiss complex intruded by granitic phases. Between the fault and Isle aux Morts at least three periods of penetrative deformation are recognised. The earlier two phases are, at least in part, responsible for the development of the gneissic banding. The later phase subisoclinally folds this banding. The highest grade of metamorphism is associated with the second event and resulted in the development of garnet, staurolite, kyanite, sillimanite, and potassium feldspar. The Port aux Basques granite intruded the gneiss in post D1 - pre D2 times.

East of Isle aux Morts the gneisses are reworked i.e., further deformed and metamorphosed. These deformations, three are recognised, overprint the gneissic fabrics and result in the development, from west to east, of shear zones, recumbent folds, and tectonic slides. During the earliest event, which is the most penetrative, the gneisses were reconstituted to a finely schistose rock such that no lithological boundary was apparent between the gneisses and a sequence of pelitic to semi-pelitic rocks, the Harbour Le Cou Group, infolded, by this event, into the gneisses. A structural and metamorphic convergence towards the basement-cover contact zone resulted in the parallel-alignment of lithological boundaries, schistosities, and intrusive rocks within it, and an apparent gradational metamorphic contact across it. Tectonic slides define the contact.

Another sequence of predominately pelitic rocks, the Bay du Nord Group, was affected by the reworking deformations. This Group is, by correlation, Lower to Middle Devonian in age, indicating that the reworking deformations are, at the oldest, an Acadian event.

The Cape Ray Fault is a 1 km. wide zone of intense deformation which separates the Cape Ray Complex from the Port aux Basques Complex. The Cape Ray Complex is correlated with the Long Range (Grenvillian) Complex of western Newfoundland and is interpreted to have formed part of the western margin of the Proto Atlantic Ocean. The Port aux Basques Complex is included in the Eastern Crystalline Belt and is interpreted to have formed part of the eastern margin of the Proto Atlantic Ocean. The Cape Ray Fault is therefore interpreted as a cryptic suture along which complete closure of the Proto Atlantic Ocean took place.

No correlation is possible between the formation of the Cape Ray Fault and the reworking of the Port aux Basques Complex and infolding of the Harbour Le Cou Group.

TABLE OF CONTENTS

CHAPTER Page

CHAPTER Page

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

Maps in folder at end.

LIST OF PLATES

TIGHT BIN

ACKNOWLEDGEMENTS

I would like to thank my supervisor Dr. M. J. Kennedy for his invaluable help and suggestions both during the field work and the compilation of this thesis. I would also like to thank Drs. Smyth and Colman-Sadd, Mr. J. G. Malpas, Mr. R. K. Stevens, Mr. B. E. Marten, and Drs. Collerson and Williams for helpful discussions. Keith Leroy, Jackie Rose, Ruben Skinner and Bob Woods are thanked for their assistance in the field. The staff of the Port aux Basques Hotel are thanked for their tireless service. This work was carried out during the tenure of a Memorial University Fellowship which is gratefully acknowledged.

CHAPTER 1

INTRODUCTION

Location and Access

The study area is located in the extreme southwestern tip of Newfoundland, and comprises approximately 200 sq. km. between Cape Ray (latitude 47°40', longitude 59°15') and Garia Bay (latitude 47° 40', longitude 58° 30'). The Trans Canada Highway runs 1 to 2 kilometers inland from the coast between Cape Ray and Port aux Basques and terminates at Port aux Basques. A subsidiary road runs eastward from Port aux Basques to Rose Blanche with minor roads leading off it to Margaree, Foxroost, Burnt Islands, Diamond Cove and Harbour le Cou. (Fig. 1). The area from Rose Blanche eastward to Garia Bay is only accessible by sea.

Physiography and Climate

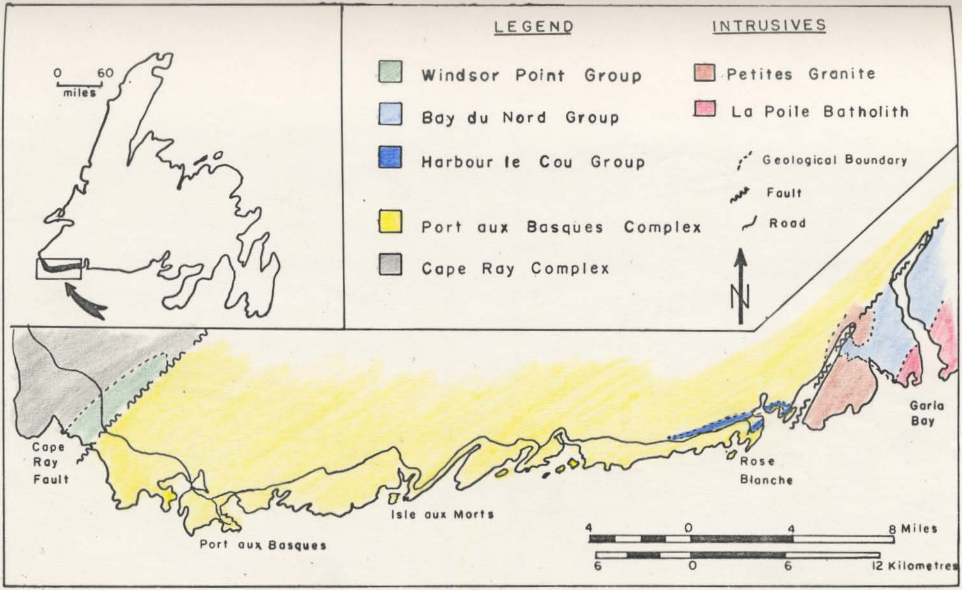
Exposure in the map area is good, especially along the coastline and up to 3 km inland. There is however a general decrease in outcrop inland from the coast. The bedrock is generally overlain by till and waterlogged peat deposits. In the valleys, where the peat deposits are quite thick, outcrop is scarce, but on the ridges the bedrock crops out through a thin veneer of peat. Much of the exposure inland is supplied by roches moutonnées which indicate a north northeast to south southwest movement of the ice. Glacial striae are not uncommon and confirm the direction of movement. Terminal morraines occur, forming transverse

Figure 1

General Geology and Access--Port aux Basques

to Garia Bay

Binding



LEGEND
Windsor Point Group
Bay du Nord Group
Harbour le Cou Group
Port aux Basques Complex
Cape Ray Complex
INTRUSIVES
Petites Granite
La Poile Batholith
Geological Boundary
Fault
Road
N
0 60
miles
Cape Ray Fault
Port aux Basques
Isle aux Morts
Rose Blanche
Garia Bay
4 0 4 8 Miles
6 0 6 12 Kilometres

barriers across the valleys and can attain heights of up to 60 to 70 m.

The valleys are densely forested, the height of the trees decreasing with increasing altitude. The ridges are, however, barren of all but the hardiest of low scrub and grasses. Drainage is poor, and small shallow ponds abound throughout the area.

Rain, fog, high winds, and temperatures from 65°F to 55°F characterize the summer months in this part of Newfoundland.

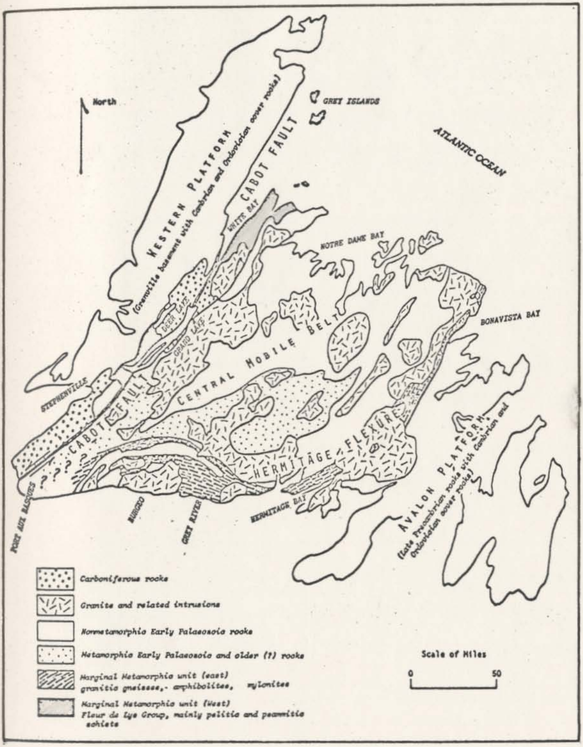
Geological Setting and Previous Work

Newfoundland is subdivided broadly into three distinct geologic subdivisions, the Western Platform (Kay, 1967), the Central Palaeozoic Mobile Belt (Williams, 1964a), and the Avalon Platform (Kay and Colbert, 1965). The Central Mobile Belt, characterized by Lower Paleozoic, variably deformed, metasedimentary and metavolcanic sequences, is bounded, to the west by the Long Range Complex of the Western Platform which extends from the Great Northern Peninsula in the north to Cape Ray in the south. To the east, the belt is bounded by the relatively undeformed Pre-Cambrian volcanic and sedimentary sequences of the Avalon Platform. (Fig. 2).

The eastern margin of the Central Mobile Belt consists of granitic gneisses, metasediments, amphibolites, and mylonites. These rocks extend in a belt from Bonavista Bay in the north, to Hermitage Bay in the south, and Williams *et al.*, (1970) suggest that they further extend along the south coast towards Port aux Basques, defining what is referred to (Williams *et al.*, *op. cit.*) as the Hermitage Flexure. Thus in the Port aux Basques area there is a convergence of the eastern and

Figure 2

General Geology and Major Structural Divisions of Newfoundland. After Williams *et al.*, 1970


North
GREY ISLANDS
ATLANTIC OCEAN
WESTERN PLATFORM
(Grenville basement with Cambrian and Ordovician cover rocks)
CABOT FAULT
WHITE BAY
NOTRE DAME BAY
DEER LAKE
GRAND LAKE
CENTRAL MOBILE BELT
BONAVISTA BAY
STEPHENVILLE
CABOT FAULT
HERMITAGE FLEXURE
AVALON PLATFORM
(Late Precambrian rocks with Cambrian and Ordovician cover rocks)
PORT AUX BASQUES
BURGEO
GREY RIVER
HERMITAGE BAY
Carboniferous rocks
Granite and related intrusions
Nonmetamorphic Early Palaeozoic rocks
Metamorphic Early Palaeozoic and older (?) rocks
Marginal Metamorphic unit (east)
granitic gneisses, amphibolites, mylonites
Marginal Metamorphic unit (West)
Fleur de Lys Group, mainly pelitic and psammitic schists
Scale of Miles
0
50

western margins of the Central Mobile Belt.

The study area was first mapped by Jukes (1843) who recognised the continuation of the Precambrian rocks of the Long Range in the Cape Ray area. Subsequent work by Murray and Howley (1881) confirmed the earlier observations. Phair (1949) regarded the Long Range igneous and metamorphic Complex as being Palaeozoic in age and tentatively correlated the marbles which are interbedded with the gneisses and schists with those in the Humber Gorge. Cooper (1954) mapped the region around La Poile Bay, east of the present map area, and outlined two gneiss complexes within a predominantly Devonian metasedimentary and metavolcanic terrain. The older of the two complexes, the Keepings Gneiss, occurs north of La Poile and was thought to be Precambrian in age. The younger complex, the Dolman Gneiss, is a sequence of paragneisses and was assigned a Devonian age. Power (1955) mapped a small area close to Isle aux Morts and Gale (1965) carried out an economic survey of the pegmatites between Isle aux Morts and Rose Blanche.

However, it was not until the work of Gillis (1972) that a regional map of the area from Cape Ray to La Poile was published. Gillis divided the gneisses of the area into three broad belts separated by the Cape Ray and Bay d'Est faults. West of the Cape Ray fault he recognised a complex of gneisses and schists which he correlated with the Indian Head Intrusive Complex near Stephenville (Riley, 1962). The gneisses east of the Cape Ray fault were tentatively assigned an Ordovician age and, in part, correlated with the Dolman Gneiss of Cooper (1954).

Brown (1972, unpublished M.Sc. thesis) mapped the coastal section from Red Rocks to Isle aux Morts Brook. He divided the area into three geologic subdivisions, the Cape Ray Complex, the Port aux Basques Complex and the Windsor Point Group. The Cape Ray Fault Zone separates the Port aux Basques Complex from the Cape Ray Complex. The Windsor Point Group overlies the Cape Ray Fault Zone. The Cape Ray Complex was assigned a Precambrian age and correlated with the Long Range Complex of Western Newfoundland. No age was assigned to the Port aux Basques Complex but it was thought to be Precambrian due to its structural and metamorphic complexity. At least three major phases of deformation and metamorphism, and one phase of granitic intrusion, were recognised. The Windsor Point Group overlies the Cape Ray Fault Zone and comprises a sequence of metasedimentary and metavolcanic rocks which are little deformed. He also recognised the fundamental nature of the Cape Ray Fault and suggested that the totally different gneissic basements on either side of the fault may be due to the juxtaposition of the eastern and western margins of the Central Mobile Belt along the fault (Brown, 1973).

The present study is an extension of Brown's (1972) work, both inland and eastward along the coast of Garia Bay. In the general Port aux Basques area, the structural and metamorhpic history, outlined by Brown (1972) is corroborated. The character of the Port aux Basques gneisses, was, however, found to change, eastwards toward Rose Blanche and, in the general area of Rose Blanche, the gneisses are reworked by renewed deformation. This reworking infolds a younger metasedimentary sequence of unknown age. A metasedimentary sequence of rocks with recognisable sedimentary features, found in the extreme east of the area, is correlated with the Devonian Bay du Nord Group of the La Poile area, (Cooper, 1954).

Pegmatites near Rose Blanche (Gillis, 1965) and Channel-Port aux Basques (Neale, 1963) yield K-Ar ages on biotite of 400±20 m.y. and

415±20 m.y. respectively. The meaning of these ages is however not clear since the pegmatites in this area are highly deformed. The Petites granite and La Poile Batholith, both of which cut the Devonian sediments, give K-Ar ages of 350±16 m.y. and 350±16 m.y. (Gillis, 1967). These both predate in part, the deformation affecting the Devonian sediments.

Justification and Methods of Present Study

This work represents an attempt to resolve two problems which became apparent during my M.Sc. study of the Port aux Basques Complex (Brown, 1972) but which were outside the scope of this study. Although the M.Sc. was restricted to the Port aux Basques area, day trips to Rose Blanche revealed that the gneisses, as observed at Port aux Basques, gradually changed character eastwards until they looked distinctly like polydeformed metasediments at Rose Blanche. An attempt was made to locate the contact between the metasediments and the gneisses. It was not found. A description of the location, character, and nature of this basement-cover contact forms the main part of the present study.

The deformations affecting the metasedimentary rocks were found to postdate those that affect the gneisses at Port aux Basques. It is suggested that the later of these two deformational sequences is Devonian in age.

The second problem is the significance of the Cape Ray Fault. During the M.Sc. study it was realised that the fault was important since it separated two contrasting gneissic complexes. Its full significance however did not become apparent until it was traced inland and stripped of its cover, the Windsor Point Group. It was found that the mylonite zone between the two basements was over 1 km. in width and that its affect on the Port aux Basques Gneiss was apparent up to 5 km. across strike. The fault is thus of regional rather than local importance and it is suggested that it represents a cryptic suture along which complete closure of the Proto Atlantic took place.

The area was mapped, using aerial photographs, on a scale of 1 : 20,000. Throughout, the principles of small scale structural mapping (Wilson, 1961) were applied. Three types of tectonic fabric were recognised i.e., L, L-S, and S tectonites (Flinn, 1965). An L tectonite is one in which the fabric element is characterised by an axial direction rather than a planar surface. An S tectonite is one in which the dominant structure is a schistosity plane. An L-S tectonite contains elements of both these types. The fabric associated with any one phase of deformation may vary across a section from an L to L-S to S tectonite due to variation in the shape of the deformation ellipsoid (Flinn, 1962) in response to variation in the stress field. Recognition and interpretation of over-printing and transposition of these elementary fabric types, in successive deformations, resulting in a composite fabric, (Whitten, 1966; Rast, 1966) form an essential part of the present study.

The nomenclature of fold types is based on Fleuty (1964) and that of cleavage on P. F. Williams (1972). For descriptive purposes five rock types are defined:

Psammite: 40% to 60% quartz. Up to 30% mica. Remainder feldspar.

Semi-pelite: 10% to 40% quartz. Remainder feldspar and mica in equal proportions.

Pelite: Less than 10% quartz. Remainder dominantly mica with minor feldspar.

Amphibolite: Over 50% hornblende. Remainder dominantly plagioclase with minor quartz.

Calc-silicate: Over 50% calc-silicate minerals.

The term gneiss is used here to denote a coarse banded metamorphic rock, within which the effects of deformation and recrystallisation have to a great extent obscured the original nature of the rock. The banding is secondary rather than primary. The term schist is used to denote a metamorphic rock within which a schistosity i.e., an alignment of mica flakes in response to deformation, is apparent. It is therefore a non genetic term in that rocks containing a schistosity occur in both the Port aux Basques Complex and the metasedimentary Windsor Point, Harbour le Cou, and Bay du Nord Groups.

Basement rocks are in part gneissic and as such have a complex deformational and metamorphic history. The term cover rocks is used here to denote metasedimentary and/or metavolcanic rocks which overlie basement rocks. Although these rocks may be deformed and metamorphosed, their tectonic history is generally less complex than that of basement rocks, and their original nature is still apparent.

Nomenclature of all other rock types is based on Holmes (1920).

The petrographic microscope was the main tool used in the laboratory and mineral identification and composition (where in a solid solution series) was made using standard identification techniques (Deer, Howie, and Zussman, 1966). Identification and interpretation of intergrain relationships is based on the principles developed by Harris and Rast (1960), Voll (1960), Kretz (1960), Rast (1966), Vernon (1968), and Spry (1969).

CHAPTER 2

BASEMENT COMPLEXES

Two basement complexes are present in the study area, the Cape Ray Complex and the Port aux Basques Complex. The former is an intensely retrogressed chaotic leucogneiss which crops out west of the Cape Ray Fault Zone. The Port aux Basques Complex crops out east of the Cape Ray Fault Zone, and is a well banded gneiss consisting of leucocratic and melanocratic bands.

Cape Ray Complex

The Cape Ray Complex crops out in the extreme western part of the study area. It is bounded to the east by the Port aux Basques Complex from which it is separated by the Cape Ray Fault and to the west by Carboniferous sediments from which it is separated by the Cabot Fault. It consists essentially of the Long Range Gneiss intruded by granitic and mafic phases (Brown, 1972) and includes a fault bounded mafic and ultramafic body (Phair, 1949). In the present study the only rock type studied within the Complex was the Long Range Gneiss.

Long Range Gneiss

The Long Range Gneiss crops out in a north east trending belt bounded to the east and west by the Cape Ray and Cabot faults, respectively. It is a coarse grained, retrogressed, leucogneiss with a grey-green aspect in the field (Plate 1). At least two tectonite fabrics were noted, both of which are intensely chloritised. The later, dominant fabric, strikes parallel to the trend of the belt and dips steeply to the south east. Stretched quartz and feldspar crystals, up to 1 cm. in length, are surrounded by augen of both fabrics. Quartz is more abundant than feldspar and locally has a bluish colour due to strain.

Chloritised and epidotised amphibolite pods and basic dykes are scattered throughout the gneiss and give it a chaotic aspect. The pods generally occur randomly and tend to be elongated with their long axes parallel to the later of the two fabrics. Swarms of these pods occur locally. Recognisable dykes are less common. They are fine grained, have a light green aspect in the field, and contain at least one tectonite fabric.

Petrography: The mineral assemblage observed in the leucocratic gneiss is quartz, feldspar, chlorite, epidote, and sericite with accessory magnetite and allanite.

There are two fabrics present in the rock. The earlier, where well developed, is defined by an intergrowth of quartz and chlorite and appears to be composite in nature. This has been reorientated by the later deformation and now forms disjointed knots in a sericite matrix. The later fabric is defined by a preferred orientation of chlorite and sericite.

Quartz occurs as porphyroblasts, around which the earlier fabric forms augen, and also as intergrowths with chlorite defining this fabric. In the former occurrence the quartz crystals are highly strained, partially recrystallised, and have sutured grain boundaries. Where intergrown with chlorite they show straight grain boundaries parallel to the (001) plane of chlorite.

The feldspars occur as porphyroblasts. They are highly altered and, close to the Cape Ray Fault are completely broken down to sericite and epidote. No definite potassium feldspar was observed. Plagioclase (An 28-42) shows well developed twins on the albite and pericline laws. Many of the twin individuals are wedge shaped and the composition planes are outlined by epidote and sericite.

The abundance of sericite in the rock is dependant on the degree of breakdown of the feldspars. Where breakdown is complete, the rock consists essentially of quartz porphyroblasts set in a sericite matrix with knots of chlorite occurring in the pressure shadows. Where the feldspars are only partially broken down sericite pseudomorphs the feldspars.

Epidote occurs as an alteration product of the feldspars and also as small rounded crystals associated with the early composite fabric. Laths and euhedral crystals of magnetite are associated with chlorite. Allanite is rare and occurs as small (less than 0.1 mm.) crystals within the composite fabric.

Port aux Basques Complex

The Port aux Basques Complex extends, from the Cape Ray Fault in the west to Garia Bay in the east. It comprises a well banded gneiss complex of leucocratic bands and melanocratic bands (Plate 2) intruded by numerous granitic phases. The banding is regular, strikes northeast and dips either southeast or northwest. The character of the gneisses changes from west to east. From the Cape Ray Fault to Isle aux Morts the melanocratic bands constitute up to 40% of the gneiss and are tightly infolded with the leucocratic bands. These latter bands show a variation in composition from a quartz-feldspar rock to a biotite-garnet rock. In this area the banding generally dips southeast.

East of Isle aux Morts the gneiss is composed predominately of quartzo-feldspathic bands with rare basic bands. The compositional variation in the leucocratic bands does not show the broad spectrum observed in the Port aux Basques area and no highly micaceous bands were observed. In this area the banding generally dips northwest.

The west - east compositional change is accompanied by a change in structural complexity. In the Port aux Basques area the gneisses have been penetratively deformed at least three times, with the last phase resulting in upright isoclinal folding of the banding. East of Isle aux Morts the gneisses are reworked, the reworking overprinting and obliterating the earlier phases of deformation. In the Isle aux Morts area the reworking is restricted to narrow shear zones which are sub parallel with the gneissic banding, and is accompanied by sulphide (pyrite) mineralisation. East of Granby Sound the gneissic banding is folded into flat lying isoclinal folds. In the Rose Blanche area these are refolded by yet another phase of deformation. The overall result of these deformations is the complete breakdown of the gneissic fabrics. A metasedimentary sequence of unknown age, the Harbour le Cou Group, is infolded into the gneisses during the reworking.

The metamorphic grade of the gneisses also shows a variation from west to east with the progressive development of garnet, garnet-staurolite-kyanite, garnet-kyanite, and garnet-sillimanite, zones from the Cape Ray fault to Isle aux Morts. East of Isle aux Morts no kyanite or staurolite was observed although sillimanite is locally abundant. In the Granby Sound - Rose Blanche area garnet is generally the only high grade mineral developed. This change in metamorphic grade is accompanied by a change in growth style. In the west the metamorphic growth is coarse i.e., garnet up to 2 cms. in diameter, kyanite up to 10 cms. in length, and staurolite up to 4 cms. in length. East of Isle aux Morts, however, the gneisses are much finer grained with a mica 'sheen' rather than a coarse mica fabric developed. Garnets are usually less than 2 mm. in diameter.

The change in character of the gneisses is accompanied by a change in the character of the granitic phases intruding the gneisses. In the Port aux Basques area they are potassium feldspar rich, and occur as sheets up to 80 m. in width which are parallel to, and folded with, the gneissic banding. No contact metamorphic effects were noted. These sheets grade into a migmatite complex in the Margaree-Foxroost area. East of Isle aux Morts the granites are leucocratic and garnetiferous, and, in places, show distinct contact metamorphic effects. These are related in time to the reworking of the gneiss, and contain the fabrics resulting from the reworking.

The reworked gneiss and the granitic phases associated with it are described separately from the main gneiss body.

Port aux Basques Gneiss

For descriptive purposes the gneissic banding of the Port aux Basques gneisses is divided into six distinctive lithologies i.e.

Leucocratic Bands:

(a) Massive (less than 10% mica).

(b) Schistose (greater than 10% mica).

(c) Migmatitic.

Melanocratic Bands:

(a) Fine Grained Amphibolites.

(b) Coarse Grained Amphibolites.

(c) Calc Silicate Bands.

This descriptive scheme follows Brown's (1972) unpublished M.Sc. thesis outline).

Leucocratic Bands.

(a) Massive.

The massive bands occur throughout the gneiss complex and may constitute up to 80% of the gneiss at any one outcrop. They are more prevalent to the east than to the west of Isle aux Morts. The bands vary in width from 1 m. to 10 m. In field aspect they are grey or white and have a granular rather than schistose texture. Two types of fabric are observed, a composite fabric and a fine schistosity. Flattened pods of mica define a fabric, giving the rock a button schist aspect. The 'buttons' are muscovite and sillimanite pods.

Garnets are poorly developed in this rock type. In bands with very low mica content the garnets, if developed, are usually less than 2 mm. in diameter and scattered sparsely throughout the rock. With an increase in mica content, especially biotite, the garnets are better developed. Locally they occur in clusters with a quartz rich biotite poor corona developed.

Petrography: The mineral assemblage is: quartz, plagioclase, potash feldspar, muscovite, biotite, ± garnet, ± sillimanite, ± accessory magnetite, apatite, and zircon.

The rock is composed essentially of quartz and feldspar with subordinate mica and garnet. A composite fabric, where developed, is defined by mica rich bands up to 3 mm. in width, separated by mica poor bands. This type of fabric is developed on fold limbs and close to shear zones. Where the fabric is not composite, two fine schistosities are observed. These are defined by single flakes of muscovite or biotite, or both, and show a strain slip relationship.

The quartz and feldspar define an equigranular polygonal texture. Quartz is the dominant mineral and occurs as strained crystals with well developed triple point junctions. Potash feldspar and plagioclase occur in variable proportions, are little altered, and usually untwinned. Plagioclase, where twinned, shows a composition range An 30-60. Twinning on both albite and pericline laws is observed.

Garnets are small (less than 2 mm.), inclusion free, and occur at grain boundaries, triple point junctions and as inclusions in quartz. Where better developed they are anhedral and contain quartz inclusions. Sillimanite var. fibrolite is rare and occurs as pods associated with white mica porphyroblasts.

Magnetite, apatite, and zircon occur as rounded anhedral crystals at grain boundaries, triple point junctions and as inclusions in the essential minerals. Magnetite also occurs as laths associated with biotite.

(b) Schistose Bands.

The schistose bands occur throughout the Port aux Basques Gneiss and may constitute up to 30% of the gneiss at any one outcrop. Individual bands vary in width from 5 cm. to 5 m. but are generally in the order of 1 m. In field aspect they are highly variable but are usually coarsely schistose with a well developed composite fabric defined by muscovite or biotite or both. The variable aspect is enhanced by the coarse development of garnet, staurolite, kyanite and sillimanite. These minerals define a metamorphic zonation in the gneisses with the development of garnet, garnet-staurolite-kyanite, garnet-kyanite, and garnet-sillimanite zones.

Garnets are ubiquitous throughout the area in the massive and schistose leucocratic bands, vary in size from 1 mm. to 2 cms. in diameter, and partially overgrow the composite fabric. Staurolite is locally developed in bands which strike through the Grand Bay area, and occurs as large, brown, elongate crystals, around which the composite fabric forms augen. Individual crystals are up to 4 cms. in length and show no preferred orientation on the schistosity plane. Kyanite is also only locally developed in bands in the Grand Bay area, although it has a greater westward extent than staurolite. It occurs as single crystals up to 10 cms. in length, on the schistosity planes, as knots of crystals around which the composite fabric forms augen, in the pressure shadows of quartz boudins, and also as kyanite boudins. Sillimanite var. fibrolite occurs east of Port aux Basques and is best developed close to the Port aux Basques granite. It usually occurs in pods and gives the rock a 'button schist' aspect in the field. The pods are composed essentially of white mica porphyroblasts which contain fibrolite needles.

Petrography: The mineral assemblage of these bands is: biotite, muscovite, quartz, feldspar, garnet, ± kyanite, ± sillimanite, ± staurolite, with accessory magnetite, zircon, sphene, allanite, and apatite.

These bands contain a composite type of fabric defined by 2-3 mm. wide mica rich bands separated by mica poor bands. This fabric has been folded and crenulated and, close to fold hinges a new axial planar fabric is developed. On the fold limbs the two fabrics are indistinguishable and a vermicular growth of mica, quartz and feldspar has resulted.

Quartz and feldspar are the dominant non-micaceous minerals. Quartz occurs as strained elongated crystals which have straight boundaries against (001) mica. Quartz- quartz and quartz-feldspar boundaries are sutured. The feldspars are usually quite highly altered. Plagioclase, where twinned, shows a composition range An 25-35. Many of the twin individuals are wedge shaped and are deformational in origin (Vance, 1961).

Garnets are well developed and occur as anhedral porphyroblasts, as inclusions in kyanite, staurolite, quartz, feldspar and mica, and at grain boundaries within the fine quartz-feldspar bands. Most porphyroblasts contain inclusions of quartz and feldspar which define both straight and curved inclusion trails. These inclusions tend to be restricted to the central part of the crystals, the rims being inclusion free. Where garnets occur, as inclusions and at grain boundaries, they are subhedral and seldom contain inclusions. Garnet-quartz bands occur within these schists. The garnets comprise up to 60% of the bands, are subhedral, inclusion free, and occur at grain boundaries and as inclusions in quartz.

Staurolite occurs as porphyroblasts and as inclusions in kyanite, quartz and plagioclase. The porphyroblasts, around which the composite fabric forms augen, locally contain straight and curved inclusion trails defined by quartz and feldspar crystals. Where it occurs as inclusions the staurolite is anhedral and does not contain inclusions.

Kyanite occurs as porphyroblasts around which the composite fabric forms augen, and as acicular crystals which help define the fabric. The porphyroblasts tend to occur in clusters and form boudinage structures. They are euhedral and almost inclusion free, although staurolite, garnet, quartz and feldspar inclusions are locally observed. The acicular crystals are euhedral or show dendritic growth with abundant inclusions.

Sillimanite var. fibrolite occurs as felted pods which define a fabric. Where kyanite and sillimanite occur together they either coexist or sillimanite replaces kyanite.

Magnetite and sphene occur with the biotite defining the composite fabric and are intergrown with it. Epidote and zircon are present as small rounded inclusions in quartz, feldspar and biotite. Well developed pleochroic haloes are associated with the zircon in biotite. Acicular apatite crystals, up to 2 mm. long are found in the fine quartzo-feldspathic bands.

(c) Migmatitic.

Granitic gneisses occur in a three kilometre wide zone between Margaree and Isle aux Morts. The zone strikes northeast in conformity with the rest of the Port aux Basques Gneiss. The granitic bands, which vary in width from 1 to 5 metres, are the dominant lithology within the zone and give the gneiss a migmatitic aspect (Plate 3). In the field they weather white and have a typical granitic texture modified by a well developed biotite fabric. This fabric has been isoclinally folded. Leucocratic 'soaks' of quartz and feldspar are common. These are pegmatitic and generally rimmed by biotite selvages.

Garnets occur along the schistosity planes and within the biotite selvages. They are poorly developed and are usually less than 2 mm. in diameter. Sillimanite is rare and occurs in pods and lenses.

Petrography: The mineral assemblage of these bands is: quartz, perthitic microcline, plagioclase, biotite, ± garnet, ± sillimanite, ± hornblende, with accessory magnetite, sphene, allanite, apatite and zircon.

The rock is composed essentially of quartz and feldspar with subordinate biotite. One well defined biotite fabric is developed. This is isoclinally folded and an axial planar fabric developed. This later fabric is recognised by the partial breakdown of quartz and feldspar and the development of either a mortar texture (Spry, 1969) or a new biotite fabric.

Quartz comprises 20% to 30% of the rock and occurs as strained crystals, with sutured boundaries, which have an interstitial habit with respect to the feldspars. Perthitic microcline with well developed grid twinning is the dominant feldspar and occurs as porphyroblasts up to 5 mm. across. The string and sheet perthite lamellae are generally restricted to the central part of the crystals and are surrounded by a variably developed lamellae free rim. Plagioclase An 15-25 is less abundant than microcline, is well twinned, and usually slightly altered to sericite. Myrmekite is well developed at microcline-plagioclase grain boundaries. The quartz rods develop at a high angle to the microcline-plagioclase grain boundary and give rise to leaf like structures.

Garnets tend to be subhedral and are associated with biotite. The main biotite fabric forms augen around, but is also partially overgrown, by these garnets. Inclusions are rare and do not form recognisable trails. Hornblende occurs as porphyroblasts showing dendritic growth which contain abundant inclusions of quartz and feldspar. Sillimanite occurs in felted pods associated with white mica porphyroblasts.

The occurrence of accessory minerals is as described for the other types of bands. Magnetite and allanite, also occur as euhedral porphyroblasts.

Melanocratic Bands.

(a) Fine grained amphibolites.

Fine grained amphibolites constitute over 90% of the melanocratic bands within the Port aux Basques Gneiss and may constitute up to 60% of gneiss at any one outcrop. The distinction between hornblende schist and amphibolite as defined by Cannon (1963) i.e., less than and greater than 70% hornblende, is not followed here since the bands generally contain between 65% and 75% hornblende. They may however contain as much as 85% and as little as 50% hornblende.

In field aspect the amphibolites are fine grained green, dark green, or black rocks and occur in bands which vary from 1 cm. to 10 m. in width. The presence of feldspar, which may constitute up to 30% of the rock, imparts a mottled or fine banded aspect to the rock. Where hornblende is the only mafic mineral present the L component of the L-S fabric is well developed. With increasing biotite content the fabric becomes a normal L-S tectonite.

Garnets are quite well developed, especially at the margins of the amphibolite. They are dark red in colour and rarely exceed 4 mm. in diameter. The fine banding forms augen around these crystals.

Petrography: The mineral assemblage is: hornblende, plagioclase (An 25-75) quartz, biotite, ± garnet with accessory magnetite, epidote, apatite, and sphene.

The rock is composed essentially of hornblende, plagioclase, and quartz. A composite fabric is well developed and is defined by hornblende rich bands up to 3 mm. wide separated by feldspar - quartz rich bands. This fabric has been isoclinally folded and, where biotite is present an axial planar fabric is developed.

Hornblende constitutes up to 85% of the rock and occurs as porphyroblasts and as small anhedral crystals showing dark green to yellow brown pleochroism. The porphyroblasts occur in augen of the fine banding, have a dendritic habit, and contain numerous small rounded quartz and feldspar inclusions. The anhedral crystals help define the composite banding and are generally inclusion free.

Plagioclase An 25-75, occurs as slightly altered subhedral crystals. Twinning, where observed, is on the albite, pericline and Carlsbad laws and the twin individuals are wedge shaped. Zonation, is generally normal, but oscillitory and reverse types are also present. Quartz occurs as strained, partially polygonised crystals, which are elongated parallel to the fine banding.

Garnet occurs as anhedral crystals around which the fine banding forms augen. Curved inclusion trails, defined by quartz, feldspar, and magnetite, tend to be confined to the central part of the crystals. Biotite occurs as poikiloblastic crystals which help define both the composite banding and the axial planar fabric associated with the folding of this banding.

Epidote occurs as small anhedral crystals and as rims around allanite. Sphene, allanite, magnetite and zircon occur as small anhedral crystals and are generally associated with biotite. Apatite is rare and is restricted to the leucocratic fraction of the rock.

(b) Coarse grained amphibolites.

The coarse grained amphibolites occur as pods and lenses up to 20 m. long around which the gneissic banding forms augen. They are commonest in the migmatite zone between Margaree and Isle aux Morts. The centres of the pods are coarsely crystalline and non schistose with hornblende constituting up to 95% of the rock. The margins are finer grained and contain a fine banding or schistosity which parallels the gneissic banding.

Petrography: The mineral assemblage of these bands is: Hornblende and plagioclase.

The rock consists essentially of euhedral hornblende showing dark green to yellow brown pleochroism. Plagioclase An 60-75, constitutes less than 5% of the rock and occurs interstitially with respect to the feldspars.

(c) Calc-silicate bands.

Calc-silicate bands are rare within the Port aux Basques Gneiss but, where found, are up to 2 m. in width and are conformable to, and folded with, the gneissic banding. They consist essentially of epidote, and their light green colour serves to distinguish them from the amphibolites.

Petrography: The mineralogy of these bands is: epidote, plagioclase, calcite, magnetite, and haematite.

Epidote occurs as subhedral to euhedral crystals up to 5 mm. in diameter and constitutes up to 95% of the rock. Plagioclase An 40 is generally saussuritised. A crude epidote-plagioclase banding defines a tectonic fabric. This fabric is isoclinally folded.

Calcite and magnetite occur as euhedral crystals with an interstitial habit. Grain boundaries and fissures are haematite stained, giving the rock a pinkish aspect.

Port aux Basques Granite

The Port aux Basques Granite occurs in sheets up to 80 m. thick between Port aux Basques and the migmatite zone at Foxroost. The sheets are conformable with the gneissic banding and do not show any contact metamorphic effects. In field aspect the rock has an equigranular to porphyroblastic texture, is pink on the fresh surface, and weathers white. Two fabrics are developed in the rock. Where the earlier is well developed an augen gneiss is produced, the augen being composed of potash feldspar and quartz. This fabric is folded, with the second fabric being axial planar to these folds. Pegmatites, associated with the granite, both cross cut and are conformable with the gneissic banding. They usually contain the two fabrics observed in the main granite body. The component minerals are coarsely developed with potassium feldspar up to 30 cms. in length.

Petrography: The mineral assemblage of the Port aux Basques Granite is: quartz, potassium feldspar, plagioclase, biotite, muscovite, with accessory zircon, sphene, apatite ± allanite ± garnet ± ferrohastingsite ± epidote.

The rock is composed essentially of quartz and feldspar. Two fabrics are present. The earlier is an S tectonite defined by aligned biotite and muscovite flakes. This fabric has been folded and an axial planar fabric, defined by a mortar texture (Spry, 1969), developed.

Quartz constitutes up to 20% of the rock and occurs as strained and partially polygonised crystals with sutured grain boundaries. The potassium feldspar content includes orthoclase, perthitic orthoclase, microcline and perthitic microcline. These generally occur as large crystals and form the augen of the augen gneiss. They are subsequently broken down by the development of the mortar texture. Twinning is best shown where the mortar texture is well developed and around inclusions of quartz and plagioclase. There are two phases of string perthite, an early fine phase and a later coarse phase. The early fine phase is restricted to the central part of the large crystals and its orientation is controlled by the microcline twin planes. The later, coarse phase, occurs over the entire crystals and its orientation bears no fixed relationship to the twin planes.

Plagioclase, An 25-30, constitutes up to 30% of the rock and occurs as well twinned porphyroblasts. Twinning is on the albite law. Where the mortar texture is well developed the porphyroblasts are broken down and the twin individuals become wedge shaped. Myrmekite occurs in both twinned and untwinned plagioclase. It is best developed where microcline is abundant and where recrystallisation, associated with the mortar texture, has taken place.

The accessory minerals occur as subhedral crystals associated with the biotite fabric. Sphene, zircon, and apatite, also occur as rounded inclusions in the feldspar porphyroblasts. Epidote occurs as rims around allanite. Ferrohastingsite is variably developed, and where abundant (up to 6% of the rock) helps define the early fabric. Garnet is rare and occurs only in the southern part of the granite. The crystals are small, subhedral, and inclusion free.

CHAPTER 3

REWORKED GNEISS

The Port aux Basques Complex is reworked i.e., further deformed and metamorphosed, east of Isle aux Morts. The new deformations overprint the gneissic fabrics, increase in intensity eastwards, and result in a transposition of the gneissic banding. Between Isle aux Morts and Granby Sound the reworking is restricted to shear zones up to 10 m wide. Within these zones (six have been recognised) the gneiss is highly schistose and a new fabric, defined by sillimanite, var. fibrolite, muscovite and biotite, is well developed. This fabric overprints and partially obliterates the gneissic banding. Sillimanite is best developed in the western zones around Isle aux Morts and overgrows white mica porphyroblasts. The eastern zones, around Granby Sound, show little development of sillimanite but white mica porphyroblasts are abundant and give the rock a 'button schist' aspect in the field.

East of Granby Sound the gneissic banding is openly folded into recumbent antiforms and synforms with axial plane trending northeast to east-northeast and dipping at a shallow angle to the northwest. This deformational event crenulates and transposes the gneissic fabrics. Porphyroblasts of white mica are quite well developed. The intensity of this deformation increases rapidly northeast along strike and southeast across strike and the gneissic banding is folded into tight recumbent sub-isoclinal to isoclinal folds. The associated axial planar fabric becomes well developed with the result that the gneissic banding is transposed and recrystallised.

The intensity of the deformation and recrystallisation is variably developed throughout the reworked zone. Where it is poorly developed the gneissic banding, with attendant composite fabrics, is still recognisable. However, where the deformation is more intense the nature of the gneisses changes considerably and the recognition of their original gneissic character becomes increasingly difficult. In the intensely reworked zone at Rose Blanche the original gneissic nature of the rocks is totally obliterated.

In the leucocratic bands the recrystallisation results in an overall decrease in grain size and the composite style of fabric, which is so characteristic of the Port aux Basques gneisses, is transposed and eventually totally obliterated. A redistribution of micaceous minerals accompanies this decrease in grain size and the rock develops a homogeneous schistose aspect, as the older mica rich- mica poor banding, as observed at Port aux Basques, becomes completely destroyed. The completely reworked gneiss has the appearance of a semi-pelitic schist with a mica 'sheen'. Remnants of gneissic banding and composite fabrics are locally found within these schists, and attest the original gneissic nature of the host rock.

Garnets are well developed in the leucocratic to schistose bands and occur either scattered throughout the rock or in discreet garnet-quartz bands. Individual crystals are generally less than 2 mm. in diameter and the coarse (up to 1.5 cms. diameter) growth commonly observed in the Port aux Basques gneisses is not found in these rocks. Thin garnet-quartz bands, up to 1 cm. in width, are continuous on outcrop and are extremely useful as marker horizons on a local scale. They show the progressive nature of the reworking deformations i.e., in the west they are openly folded and crenulated whilst in the east at Rose Blanche they are isoclinally folded with the limbs sheared out.

Melanocratic bands are relatively rare within the reworked zone and are found at the Barasway and in the Rose Blanche area. At the Barasway they occur as coarse grained boudins up to 10 m. long and 2 m. wide. (Plate 4) The mineralogy is totally different from that of the basic bands at Port aux Basques and consists of cummingtonite - phlogopite - quartz and apatite. Two ages of cummingtonite growth are recognised, an early iron poor non-pleochroic type, and a later iron rich, slightly pleochroic in green, variety. Apatite occurs as euhedral crystals and is peculiar in that it is biaxial negative with a 2V of approximately 15°, rather than uniaxial.

In the Rose Blanche area the melanocratic bands are fine grained amphibolites which are very similar to those observed in the Port aux Basques to Isle aux Morts area. They consist essentially of green hornblende, plagioclase and quartz with accessory fuchsite close to the margins.

Calc-silicate bands are uncommon in the reworked zone but are found at the Barasway, Harbour le Cou, and on the eastern shore of Harbour le Cou Bay. At the Barasway they occur as boudinaged lenses up to 15 m. in length and 3 m. wide, and conform to the gneissic banding (Plate 5). Unlike their counterparts in the Port aux Basques Gneiss these bands show a varied mineralogy and consist of garnet - diopside - hornblende -

zoisite - clinozoisite - epidote - plagioclase - quartz - calcite - sphene, and apatite. The garnets are of the grossular variety (cell dimension 11.88Å) and show cyclic growth with zoisite, clinozoisite, epidote and calcite. Diopside occurs as a relatively minor constituent and has been altered to hornblende. Plagioclase has a composition An 80 and is generally slightly retrogressed to zoisite and sericite. Calcite is ubiquitous throughout the rock. Sphene occurs in the groundmass and shows red brown pleochroism. Apatite is a minor accessory and occurs as inclusions in grossular.

At Harbour le Cou, one calc- silicate pod of unknown extent was found at a granite contact. A mineralogical ~~banding~~ is present consisting of wollastonite, calcite, garnet and vesuvianite, xonotlite, and apatite. Quartz occurs throughout the rock. The bands are up to 1 cm. in width and are parallel to the granite contact. The mineralogy of the bands varies with distance from the granite. Close to the contact calcite, wollastonite and apatite predominate. The wollastonite occurs in radiating columnar aggregates and has subsequently been retrogressed to calcite. Apatite occurs as subhedral acicular crystals up to 2 cm. in length and also shows retrogression to calcite. Farther from the contact calcite, garnet - vesuvianite - apatite, and xonotlite bands predominate. The garnet - vesuvianite - apatite bands show an intimate intergrowth of garnet and vesuvianite. The vesuvianite is recognised by its anomolous blue interference colours. Apatite occurs as inclusions within this intergrowth. Quartz constitutes up to 20% of these bands.

One 1 cm. wide band of xonotlite was found. This mineral is dark purple on the fresh surface but weathers to a light pink. In thin section it appears to be altered to a carbonate, and the optics are inconclusive. X-ray diffraction results gave a positive identification. (Appendix 2).

On the eastern side of Harbour le Cou Bay calc-silicate bands up to 1 m. wide are intensely flattened and folded by the reworking deformations. Vesuvianite, quartz and calcite are the main constituents of these bands. The vesuvianite has very low birefringence, shows anomolous Berlin blue interference colours, and both uni-axial and bi-axial varieties are present. Positive and negative figures were noted. Calcite, sphene, tremolite, and clinozoisite comprise the remainder of the rock.

Three major and two minor tectonic slides have been recognised within the reworked zone. These strike east northeast, dip at a moderate angle to the northwest, and are parallel to the reconstituted gneissic banding. They show a lithological variation along their length from a black, glassy quartz rich mylonite to a graphitic sericite schist.

The southern major slide, the Rose Blanche Slide, extends from Duck Island to Bay le Moine. It separates basement rocks to the south from basement with infolded cover rocks, the Harbour le Cou Group, to the north. It is predominantly a black, quartz rich mylonite with milky quartz pods and stringers.

The central slide, the Diamond Cove Slide, can be traced from Mull Face Bay to Bay le Moine, and separates basement rocks in the north from basement with infolded cover rocks to the south. From Mull Face Bay to Rose Blanche the slide is predominately a black quartz rich mylonite with abundant milky quartz pods and stringers. The largest of these pods occurs at Diamond Cove and is 100 m. long and 30 m. wide. Pyrite, chalcopyrite, sphalerite, and trace gold and silver are associated with this pod. East of Rose Blanche the slide gradually changes character and becomes a sulphide stained crush zone within which the character of the pre-existing rocks is totally obliterated. (Plate 6).

The northern slide the Harbour Le Cou Slide, can be traced from the Barasway to east of Harbour le Cou, and separates cover rocks to the north from basement rocks to the south. Lithologically it is similar to the southern slide. The cover rocks close to the slide in the Harbour le Cou area are button schists. The buttons are sillimanite var. fibrolite pods associated with white mica porphyroblasts. They are ellipsoidal in outline with the long axis being approximately three times the length of the short axis. The long axis plunges 45 degrees to the west-southwest.

The minor slides are lithologically similar to the southern slide and crop out east of the Barasway and at Rose Blanche. Both are well developed on the coast but appear to die out inland.

A second phase of deformation affects the reworked gneisses. This deformation folds and crenulates the earlier reworking fabric, the slide zones, and the gneissic fabrics where preserved. It is, however not as intense as the first phase and is only present east of the Barasway. The intensity increases from west to east towards Bay le Moine and an axial planar fabric defined by muscovite and biotite is well developed in the eastern part of the area.

A final open warping about a north south axis affects all the previous fabrics.

Rose Blanche Granite

The Rose Blanche Granite occurs as sheets up to 100 m. thick which strike northeast to east northeast and dip at a shallow angle to the northwest. In field aspect the rock has a granular texture and varies in colour from pink to white. The western sheets show little deformation and hornfels textures are observed in the surrounding gneisses. The eastern sheets are quite schistose, have been deformed twice and evidence of hornfelsing of the country rock is only preserved in the calc silicate bands. Garnets, although sparse are ubiquitous. Later, related, fine grained, leucocratic granite dykes generally show a much better development of garnets. Pegmatites are rare but are observed to cross cut the main granite sheets. They are coarse grained and show a fine garnet rich banding parallel to the margins of the dykes.

The composition variation within and between sheets varies from granite to granodiorite. The granites are pink to white on the weathered surface and have biotite as the mafic phase. The granodiorites weather white and have hornblende as the mafic phase. Muscovite is the dominant mica in the late dykes.

In the Rose Blanche area the margins of the granite are generally marked by extreme contamination. Xenoliths of country rock comprise up to 60% of the granite and locally show resorption. Most of the fragments are gneissic and are elongated parallel to the granite-gneiss contact. At Mull Face Bay a perfectly square basic inclusion was found (Plate 7). It is suggested that this xenolith was a joint fractured amphibolite.

Petrography: The mineral assemblage is: potassium feldspar,

AT BINDING

plagioclase, quartz, garnet, biotite, ± chlorite, ± epidote, ± allanite, ± apatite, ± hornblende, ± tourmaline, ± zircon.

The granite is a composite body varying in composition from granite to granodiorite, with the granodiorite phase being earlier than the granite phase. The western sheets have been deformed once and a mortar texture developed. Mica flakes are aligned parallel to this texture and crudely define a fabric. The central sheets contain two well developed fabrics defined by aligned mica flakes. These fabrics can be related to the deformations in the surrounding rocks.

Potassium feldspar constitutes from 10% to 40% of the rock and is generally microcline or perthitic microcline. In the larger crystals (up to 1 cm. across) inclusions of plagioclase and quartz are abundant. Plagioclase, An 18-35, constitutes 10% to 30% of the rock and generally occurs interstitially with respect to the potassium feldspar. Many crystals show a normal zonation from core to rim. Alteration to sericite is common and results in 'turbid' crystals, and discreet mica flakes along the twin and/or cleavage planes. The zonation is emphasised by preferential alteration.

Quartz comprises up to 20% of the rock and occurs interstitially with respect to the feldspars. The crystals are generally strained and have highly sutured boundaries. A vermicular intergrowth of quartz and plagioclase i.e., myrmekite is present throughout the entire body. It is however best developed in the eastern sheets where the deformations are more intense. The occurrence of this intergrowth seems to be related to the presence of microcline and to the deformation of the rock, i.e., it is most common where microcline is abundant and where it is partially broken down by the development of the mortar texture.

Garnets are ubiquitous throughout the sheets and occur in both granite and granodioritic phases. Individual crystals are generally less than 2 mm. in diameter, light pink in colour, subhedral to euhedral, and inclusion free. Locally however they show two phases of growth and contain inclusions. Inclusion-free crystals are found included in microcline crystals suggesting an igneous origin for at least some of the garnets.

Muscovite and biotite occur in knots and as individual crystals which help define the tectonic fabrics in the rock. The biotite is retrogressed to chlorite. Hornblende is the dominant mafic phase in the granodiorite and occurs interstitially with respect to the feldspars. Allanite, apatite and tourmaline are minor accessories and occur at grain boundaries. Epidote occurs as inclusions in plagioclase and is a breakdown product of that mineral. Zircon is included in biotite crystals.

Table 1

Distribution of Lithologies in the Port aux Basques Complex

		Cape Ray Fault to Grand Bay	Grand Bay to Margaree	Margaree to Isle aux Morts	Reworked zone			
					Isle aux Morts to Burnt Is.	Burnt Is. to Granby Sound	Granby Sound to Barasway	Barasway to Rose Blanche
Calc silicate rocks			(x)					(x)
Psammites		x	x	x	xx	xx	x	x
Pelites	Gt.	x	xx	x	x	x	xx	xx
	St.		(x)					
	Ky.		x					
	Sill.		x	x	x			x
Semi Pelites		x	x	x	x	x	xx	xx
Amphibolites		xx	xx	xx	x	x	(x)	(x)
Migmatites				xx				
Port aux Basques Granite		?	xx	xx	x			
Rose Blanche Granite					(x)	x	x	xx

Key: (x) Rare; x Normally present; xx Abundant.

CHAPTER 4

METASEDIMENTARY COVER ROCKS

Three Groups of metasedimentary cover rocks are present in the area, the Windsor Point Group, the Harbour le Cou Group, and the Bay du Nord Group. The Windsor Point Group occurs in the western part of the area, overlies the Cape Ray Fault Zone, and rests unconformably on the Cape Ray Complex. The Harbour le Cou Group is infolded with the Port aux Basques Complex in the Reworked Zone and extends from The Barasway to the western side of Bay le Moine. The Bay du Nord Group occurs in the extreme east of the area and extends from the western side of Bay le Moine to Garia Bay.

Windsor Point Group

The Windsor Point Group is a series of metasedimentary and metavolcanic rocks of unknown age, which crop out in a 1 km. wide and 3 km. long belt just south of Cape Ray. The Group consists of ignimbrites, tuffs, conglomerates, shales, and rhyolites, which strike north-east parallel to the length of the belt and dip steeply south-east. To the south-east the belt is fault bounded against the Port aux Basques Complex. The south western extent is marked by ignimbrites unconformably overlying the Cape Ray Complex. To the north-east the Group overlies a mylonite zone (the Cape Ray Fault Zone) which separates the Cape Ray Complex from the Port aux Basques Complex.

The general stratigraphic sequence youngs from north-west to south-east. Ignimbrite with arkose bands up to 1 m. thick unconformably overlie the Long Range Gneiss. These pass up into a tuffaceous sequence with crystal tuff and chert bands. Bands of conglomerate up to 2 m. thick occur in the south eastern portion of the tuffaceous unit. These become more numerous upwards until the rock is eventually conglomeratic. To the south-east the conglomerates pass abruptly into rhyolites with shale bands. These are separated from the Port aux Basques Complex by the Cape Ray Fault.

Deformation increases in intensity north-west to south-east towards the Cape Ray Fault, and related planar structures are parallel to the trend of the fault. Two distinct episodes of penetrative deformation can be recognised. Minor faults and kink bands cut these penetration structures. The kink bands are normal (Dewey 1969) and strike north north-east or east south-east.

Ignimbrite Sequence

The ignimbrites show a progression from a black, glassy, essentially shard free rock at the base, through a grey fragment rich and poorly welded rock, to an agglomeratic, haematite rich rock at the top of the sequence. Phenocrysts of quartz and feldspar are abundant in the basal and middle sections of the sequence. The fragments in the middle section are volcanic in origin and vary from pumice, with fiammé structures, to flow banded rhyolite. The upper part of the sequence contains volcanic and gneiss fragments. The gneiss fragments are all derived from the Cape Ray Complex, and are up to 30 cms. in diameter. Discontinuous horizons of coarse arkose occur in this part of the sequence.

Tuffaceous Sequence

The tuffaceous sequence is comprised of fine grained green tuffs with crystal tuff and brown chert beds. Thin conglomerate beds occur in the western part of the section.

Two sub-parallel penetrative cleavages are developed. Both strike northeast, dip steeply to the southeast, and increase in intensity eastwards. This results in a 2-3 mm. wide tectonic banding comprised of quartzo-feldspathic and epidote rich bands.

Sedimentary features in the tuffs are obscured by the development of the banding. One set of cross beds was however found in one of the chert beds. The succession youngs eastward.

Conglomerate Sequence

The conglomerate sequence occurs to the east of the tuffaceous sequence and consists of conglomerate beds up to 8 m. thick interbedded with fine tuffaceous material. The lower contact with the tuffaceous sequence is conformable and gradational. The composition of the pebbles is highly variable with volcanic, granitic, and gneissic varieties occurring. The volcanic pebbles are rhyolitic in composition and are similar to the ignimbrite sequence described above. The granitic pebbles closely resemble the Cape Ray Granite, and the gneissic varieties are derived from the Cape Ray Complex. No pebbles resembling the Port aux Basques Gneiss were found. The pebble diameter varies from 1 to 10 cms., and all are well rounded.

The matrix material is fine grained and tuffaceous and, where banded the banding forms augen around the pebbles. This is a tectonic rather than sedimentary banding (Plate 8) since it is axial planar to folds of the sedimentary banding. Where the banding is not developed a penetrative cleavage forms augen around the pebbles.

Rhyolite Sequence

The rhyolite sequence occurs between the conglomerates and the Cape Ray Fault. They pinch out to the northeast bringing the conglomerates into juxtaposition with the fault.

The rhyolite is a fine grained pinkish rock with a 2 to 5 mm. wide banding of alternating dark and light layers. Quartz and orthoclase phenocrysts are contained within augen of the banding. The light bands are quartz-feldspar rich and the dark bands are chlorite rich.

Muscovite and chlorite define a tectonic fabric. Subsequent deformation has isoclinally folded this fabric and an axial planar fabric developed. The fabrics are parallel on the fold limbs.

Minor shale bands, up to 15 cms. wide, occur within this unit. They are continuous and contain the same tectonic fabrics as the rhyolite.

Harbour le Cou Group

The name Harbour le Cou Group is here proposed for a sequence of metasedimentary rocks which crop out in the Harbour le Cou area. The Group occurs as two thin slivers, each less than 50 m. wide, which have a lateral extent from north of the Barasway to Bay le Moine. The northern sliver extends from north of the Barasway to east of Harbour le Cou and is bounded, to the south, against basement rocks of the reworked zone by a tectonic slide. The northern boundary, against basement ~~rocks,~~ is poorly exposed, but is in part a tectonic slide. The southern sliver extends from Rose Blanche to Bay le Moine. Its western extent is marked by what is thought to be a conglomerate (Plate 9). At Shark Cove the group is bounded to the north and south against basement rocks by tectonic slides. In the Rose Blanche area the boundaries are poorly exposed but are, at least in part, tectonic slides.

The northern sliver consists essentially of variably deformed and metamorphosed pelitic to semi pelitic schists with fine interbanded psammites. No definite sedimentary features were observed. In field aspect the rocks always display a fine mica 'sheen' rather than a composite fabric which is so characteristic of the gneisses. There is a marked compositional change along strike from west to east. To the west the Group consists of semi pelitic schists and psammites. Eastwards towards Harbour le Cou, the psammites decrease in abundance and the succession becomes dominantly pelitic to semi-pelitic.

At least two fabrics are always observed in these rocks. The earliest is developed throughout the entire section but is best preserved in the east. It is defined by individual flakes of muscovite and biotite. Where the boundary of the Group is defined by a tectonic slide the micas, defining the early fabric, increase in size towards the slide. Aggregates of white mica, up to 4 cms. in length, are developed close to the slides. These were found to contain sillimanite var. fibrolite.

The second fabric is poorly developed in the west but becomes progressively better developed eastwards toward Harbour le Cou where it is the dominant fabric in the rock. It strikes northeast and dips at a moderate angle to the northwest. In the west it is defined by individual mica flakes. Its progressive development eastwards is accompanied by a transposition of the early fabric, and results in a composite fabric.

In thin section these rocks are seen to consist essentially of quartz, feldspar and mica, in variable proportions depending on whether it is a psammite, semi pelite or pelite. Quartz is more abundant than feldspar and occurs as strained crystals which vary from 0.1 mm. to 0.3 mm. in diameter. Where the second fabric is well developed the quartz crystals are elongated in the plane of this fabric. Potassium feldspar is more abundant than plagioclase (An 20-25), especially in the eastern part of the section.

In the west the quartz and feldspar crystals defining the groundmass of the rock, are strained, have sutured boundaries, and contain abundant inclusions of opaque minerals. Eastwards towards Harbour le Cou the groundmass becomes progressively polygonised and the crystals become subhedral, inclusion free, and have straight boundaries.

Garnets are developed throughout the entire section and occur either in discreet bands or scattered throughout the rock. They tend to be euhedral and less than 0.3 mm. in diameter. The cores are almost always murky and filled with inclusions. These define trails or radial growth patterns. A clear, inclusion free, rim surrounds the murky cores.

Two types of garnet rich bands are developed i.e., garnet-biotite bands and garnet-quartz bands. The former appear to be the result of original chemical variation within the sediments, and may be a reflection of bedding, i.e., they show a complete gradation from garnet-biotite, through garnet-biotite-quartz, to garnet-quartz or biotite-quartz, and eventually to quartz rich bands and there is usually a sharp contact between the garnet-biotite and quartz rich bands. The second type of garnet rich bands is only developed in the eastern part of the section where the second fabric transposes the first. These are primarily tectonic in origin and are similar to the garnet rich banding developed in the gneisses.

Sillimanite var. fibrolite is found in the pelites close to the tectonic slide at Harbour le Cou. It occurs in pods up to 3 cms. in length which are alligned parallel to the second fabric. The pods are in general surrounded by white mica.

Accessory tourmaline is ubiquitous and occurs as inclusions in quartz and at triple point junctions where the groundmass is polygonised. Locally it is observed to overgrow the early fabric. It is common within the tectonic slides.

The southern sliver, extending from Rose Blanche to Bay le Moine is essentially similar to the northern sliver. The composition of the sediments is semi-pelitic to psammitic. A conglomerate? horizon at Rose Blanche is taken as the western extent of the sliver. Only one outcrop of this rock was found. It is a coarse schist with stretched pebbles up to 20 cms. in length and 4 cms. in width. The most common pebble composition is garnet-quartz. However, granitic fragments and fuchsite stringers were observed. It is not certain whether this rock is in fact a conglomerate since the garnet-quartz 'pebbles' are remarkably similar to the tectonic garnet-quartz bands. These pebbles? may therefore be sheared out fold limbs which result from intense flattening during the second deformation.

These sediments are more coarsely schistose than those in the northern sliver and a more composite style of fabric is developed. Polygonisation of the groundmass is well developed. Garnets are present both in bands and scattered throughout the rock, and usually have murky cores. At Shark Cove these murky cores show extremely well developed radial growth patterns which, in appearance are similar to the chiastolite cross of andalusite. The cores are always surrounded by inclusion free rims.

Although mica pods are quite common, sillimanite is rare. Tourmaline is a common accessory and appears to overgrow the composite fabric.

Bay du Nord Group

The Bay du Nord Group was first named and described by Cooper (1954) in the type area north of La Poile. In the La Poile area the Group consists of sedimentary rocks, largely clastic in origin, which are little deformed and contain fossils of Lower Middle Devonian age. The sedimentary rocks which crop out in the Garia Bay and Little Garia Bay area (this work) are thought to be the along strike equivalents of the Bay du Nord Group (Williams 1967, Gillis 1972). These rocks are bounded to the north by the Bay le Moine fault and the Petites Granite, to the south by the Petites Granite, and to the east by the La Poile Batholith. The only direction in the study area in which they are continuous is northeast i.e., along strike towards the fossil bearing Bay du Nord Group as described by Cooper (1954).

The Group consists essentially of slates and phyllites with interbedded psammites, grits, and conglomerates. One calcareous bed was found. Three fabrics are developed. The earliest is poorly developed in the east, and to the west is preserved as inclusion trails in MP1 porphyroblasts and between the S2 schistosity surfaces. S2 is the main schistosity and is usually parallel or sub parallel to bedding planes. This deformation folds the D1 structures and refolds the bedding. The third deformation crenulates the second fabric and appears to be related to a large scale antiform to the east of the area.

Regional metamorphism associated with these deformations is restricted to the greenschist facies. The Petites granite hornfelses the metasediments, and porphyroblasts of andalusite and cordierite are developed in the phyllitic beds. Hornfelsing, associated with the La Poile Batholith, is restricted to the development of biotite within 50 m. of the contact.

Slates and Phyllites

Slates and phyllites comprise the greater part of the Bay du Nord Group in the Garia Bay area. Individual beds are in the order of 5 cms. to 1 m. thick, strike northeast, and dip steeply to the northwest or southeast. The bedding planes are locally defined by thin (2-5 mm.) silt bands.

Muscovite, quartz and feldspar are the main constituents of the rock, with quartz varying from 5% to 30%. The slaty cleavage is best developed in the western part of the Group and is defined by a parting in the rock along which mica flakes are orientated. Where there is a small discordance between cleavage and bedding the fine silt layers are injected, parallel to the slaty cleavage, into the shales.

Porphyroblasts of andalusite and cordierite, associated with the hornfelsing by the Petites granite, are best developed in this rock type. The later fine schistosity forms augen around these porphyroblasts.

Psammites

Psammites occur in beds up to 2 m. thick and are subordinate to the slates and phyllites. They are very fine to fine sands (Pettijohn) both interbedded with the slates and as bedded sequences up to 20 m. thick. Cross bedding and graded bedding are quite common and facing directions are obtained from these beds. Heavy mineral separation is noted at one locality, where detrital garnets form the base of cross beds. In general the graded bedding is defined by an upward decrease in quartz and feldspar grain size and increase in mica content.

Slump features are uncommon but one well brecciated fine sandy bed within a fine sandstone sequence was observed. All the fragments are well bedded and the bed, although showing pinch and swell features, is continuous across the outcrop (Plate 10).

Quartz, feldspar, and mica are the main constituents of the rock. The cleavage is poorly developed. The later schistosity is quite well developed in the western part of the section. Hornfelsing, by the Petites granite, results in the growth of biotite, and, in the more calcic layers, actinolite. The detrital garnets show an inclusion free metamorphic overgrowth, and since, at this locality the regional fabric is poorly developed, the growth is attributed to a contact rather than regional effect. Hornfelsing by the La Poile Batholith results in the growth of biotite close to the contact.

Grits and Conglomerates

Coarse grits and conglomerates are found as discreet beds up to 1 m. thick and form a very minor part of the succession at Garia Bay. These beds thicken to the northeast and Cooper (1954) records a 500 m.

thick conglomerate. The grits are composed of well sorted quartz and feldspar up to 0.5 mm. in diameter. Feldspar consitutes up to 40% of the rock and generally occurs as smaller grains than the quartz. The sedimentary features are partially obliterated by the development of the tectonic fabrics.

Only one conglomerate bed was found in the area (Plate 11). The pebbles are up to 3 cms. in length and have a bimodal origin i.e., granite or shale. The former is more dominant than the latter. The matrix is made up of fine grained quartz and feldspar. A tectonic fabric forms augen around the pebbles.

Environment

The depositional environment of the Bay du Nord Group is thought to be pro-delta (Reineck-Singh, p. 273, 1973) due to:

(a) The lack of red beds.

(b) The general fine grained nature of the rocks except for the rare grit and conglomerate beds.

(c) The preponderance of graded rather than cross bedding.

(d) The presence of slump breccias.

Cooper (1954), on the basis of fossil plants, suggested a deltaic origin for the Bay du Nord Group to the north of La Poile Bay. These fossils were identified as *Drepanophycus spinaeformis* by Ealing Dorf (1943). Samples collected by the author, from the fossil localities described by Cooper, were identified as *Teniocrata* (W. Forbes, pers. comm. 1974). These give an age of Lower to Lower Middle Devonian for the Group.

CHAPTER 5

EASTERN GRANITES

Two granites crop out in the eastern part of the area, the Petites Granite and the La Poile Batholith. The Petites granite is a massive coarse grained equigranular granite which intrudes and hornfelses the Bay du Nord Group. A chilled margin is developed at the intrusive contact with the Rose Blanche Granite. The La Poile Batholith is a megacrystic potassium feldspar rich granite which intrudes and hornfelses the Bay du Nord Group.

Petites Granite

The name Petites Granite is here proposed for the granite which crops out in the Bay le Moine - Little Garia Bay area. It is an equigranular coarse grained potassium feldspar granite. It intrudes all surrounding rocks and therefore post dates them. To the north a chilled margin is developed in the Petites Granite at the intrusive contact with the Rose Blanche Granite. Where it cuts the Devonian Bay du Nord Group the contact is very irregular, with embayments of granite along the slate bands. The growth of andalusite and cordierite porphyroblasts within these bands is related to contact metamorphism.

One poorly developed tectonic fabric occurs locally within the granite. Movements on the Bay le Moine fault result in a northeast-southwest and northwest southeast fracture pattern. The fractures are filled with milky quartz. Molybdenite mineralisation is associated with the northwest-southeast fractures. Late dykes are uncommon.

Petrography: The mineral assemblage is: potassium feldspar plagioclase, quartz, biotite, muscovite, chlorite ± epidote. The rock is composed essentially of potassium feldspar and plagioclase with interstitial quartz. The potassium feldspar constitutes up to 50% of the rock and is generally microcline with Carlsbad twins. Crystals up to 1 cm. in length are not uncommon and usually contain inclusions of plagioclase and quartz. Plagioclase consitutes 20% - 40% of the rock and has a composition range An 25-35. Twinning on the albite law is well developed. Alteration, especially along the twin planes to sericite and epidote is common. The plagioclase included in potassium feldspar has a similar composition and alteration as that in the groundmass.

Quartz occurs interstitially with respect to the feldspars. It constitutes approximately 30% of the main body of the granite but 50% in the chilled margin. The crystals are anhedral, show sutured boundaries and are slightly strained. Biotite occurs as knots at quartz triple point junctions and is retrogressed to chlorite. Muscovite occurs as single laths and as an alteration product, with sericite and epidote, of plagioclase.

La Poile Batholith

The La Poile Batholith is a megacrystic, potassium feldspar, biotite granite which was first named by Cooper (1954) and forms the south eastern margin of the present map area. It is a very distinctive rock with large pink potash feldspar crystals 2-4 cm. in length set in a chlorite matrix. It has been deformed at least once. At Little Garia

Bay the contact between the granite and the Bay du Nord Group is fault bounded. At Garia Bay the granite clearly intrudes and hornfelses the sediments (Plate 12). The contact is highly irregular with apophyses of granite intruding into particular beds in the sediments. A hornfels texture (biotite) is developed up to a 100 m. from the contact.

One tectonic fabric is well developed throughout the granite and is defined by a mortar texture. Late aplite dykes are quite common and generally strike northeast and dip northwest i.e., parallel to the contact. Close to the contact inclusions of sediment are common. These contain large potassium feldspar porphyroblasts. The sediments show a hornfels texture and the growth of the potassium feldspar is related to potassium metasomatism and restricted nucleation.

Petrography: The mineral assemblage is: potassium feldspar, plagioclase, quartz, biotite, chlorite ± sphene, apatite, epidote and zircon.

The rock consists essentially of potassium feldspar megacrysts (60% - 70%) set in a groundmass of plagioclase and quartz. An anastomosing mortar texture is quite well developed. The potassium feldspar is microcline with well developed cross hatched twins. Crystals up to 4 cms. in length are quite common and generally contain numerous inclusions of quartz, plagioclase, sphene and biotite. Plagioclase is altered to sericite and no composition was determined.

Quartz occurs interstitially with respect to the feldspar and as inclusions in potassium feldspar. The crystals are strained and fractured and have highly sutured boundaries. The biotite and chlorite occur as inclusions in potassium feldspar and at quartz triple point junctions and grain boundaries. The biotite is retrogressed to chlorite. These minerals help define the mortar texture. Sphene occurs as subhedral crystals included in potassium feldspar and at grain boundaries. Apatite and epidote are associated with biotite - chlorite knots. Zircon occurs as intlusions in biotite.

CHAPTER 6

STRUCTURAL HISTORY

Introduction

The structural history of the area is described in terms of successive deformational episodes and their resultant fabrics, and the relationship of one fabric to another. Each group of rocks i.e., the Cape Ray Complex, the Port aux Basques Complex, the Reworked Zone, the Harbour le Cou Group, ~~the Bay du Nord Group~~, and the Windsor Point Group, is described separately and the deformation history of each group outlined, using the terminology D1, D2, etc. At the end of each section the deformational history of the group is summarized and the relationship of this history to that in other groups outlined.

Those deformations which affect only basement rocks are termed D1 (basement), D2 (basement) etc. Those which affect only cover rocks or cover and basement rocks are termed D1 (cover), D2 (cover) etc. Thus within the Port aux Basques Complex the early deformations are termed D1 (basement) etc., whilst the later deformations which overprint the early fabrics and also affect cover rocks, the Harbour le Cou Group, are termed D1 (cover) etc.

There is a significant difference between the terms D1 (cover) and D1 (basement). D1 (cover) implies that, within the cover sequence being described, this is the first deformational event to affect these rocks. In the case of the Reworked Zone, D1 (cover) which overprints gneissic fabrics, can be traced into cover rocks, and is the first deformational event to affect these cover rocks. D1 (basement), however merely implies that this is the first deformational event that has been recognised within the basement complex, and it is fully realised that earlier events may have taken place but that evidence for them has either not been observed or has been obliterated by the later deformations. Basement deformations do not, of course, occur in cover rocks.

Cape Ray Complex

Within the Cape Ray Complex a sequence of structural events can be recognised. These structures cannot, however, be used to outline a regional structural pattern for the Complex due to the limited area studied within the Complex and the poor quality of outcrop.

The oldest structures observed, D1 (basement), are preserved in basic pods which are included in the leucocratic Long Range Gneiss. The structures usually consist of a crude L-S tectonic fabric defined by hornblende, although fragments with a well developed fine gneissic banding are observed. The development of this fabric is highly variable from one pod to the next.

The Long Range Gneiss contains two tectonic fabrics, both of which form augen around the basic pods described above. The earlier of the two, D2 (basement), is defined by an intergrowth of chlorite, quartz and feldspar. It is only rarely preserved. The later fabric, D3 (basement), defined by chlorite and quartz strikes northeast, and dips steeply to the southeast and is the dominant fabric observed in the complex. The development of this fabric is highly variable across strike even over distances of 1 m. or less. Where it is well developed it completely transposes the earlier fabrics.

The Cape Ray Granite, which intrudes the Long Range gneiss, contains both these fabrics, with the later one generally totally transposing the earlier.

Towards the Cape Ray Fault the fabrics in the Long Range gneiss are overprinted by a mylonitic fabric which is related to the development of the Cape Ray Fault. S3 is parallel to the mylonite fabric and due to lack of outcrop, the age relationship between these two could not be definitely resolved. It is tentatively suggested that the two are of equivalent age since neither is observed to affect the other, they are parallel and the inhomogeneous development of the D3 fabric conforms to the tectonic regime of the development of the mylonite.

Summary

D1 (basement): Poorly developed L-S fabric preserved in basic pods. The local development of a fine gneissic banding suggests earlier events which are not chronicled here.

D2 (basement): Well developed fabric defined by quartz, chlorite and feldspar almost totally transposed by D3.

D3 (basement): Dominant fabric in the Cape Ray Complex. Defined by chlorite, sericite and quartz. Inhomogeneously developed. May be related to the development of the Cape Ray Fault.

The Cape Ray Complex and attendant deformations described above predates the formation of the Cape Ray Fault and the deposition and subsequent deformation of the Windsor Point Group. The age relationship between this Complex and the Port aux Basques Complex could not be determined.

Port aux Basques Complex

Between the Cape Ray Fault in the west and Isle aux Morts in the east, the Port aux Basques Complex shows a complex sequence of deformational events. The early phases are, at least in part, responsible for the development of the gneissic banding. The later phases fold this gneissic banding. East of Isle aux Morts the gneisses are farther deformed and result in what is termed the reworked zone. These deformations overprint the previous fabrics and are described separately. In the western part of the Complex, narrow zones of intense deformation overprint the gneissic fabrics. These zones are related to the Cape Ray Fault and will be described in the chapter relating to that fault.

The earliest observed phase of deformation, D1 (basement) is very poorly preserved and, over most of the area, its existence is inferred from the composite nature of the D2 (basement) fabric. However, at Channel Head, one F2 fold was observed to fold a pre-existing fabric.

The second phase of deformation, D2 (basement) was preceded by the intrusion of the Port aux Basques Granite. The granite, which occurs in sheets, is generally parallel to the gneissic banding, and makes an excellent marker horizon. The large scale structural patterns of both D2 and D3 are based, to a great extent, on the outcrop pattern of the granite. The second phase of deformation results in flat lying isoclinal folds which are overturned to the northwest. The axial plane of these folds trends northeast and the axial planar fabric is always parallel to the gneissic banding.

The third phase of deformation, D3 (basement) results in upright subisoclinal folds of the gneissic banding with the axial plane striking northeast and dipping 60° to 80° to the southeast. These folds are characterised, on all scales, by numerous parasitic folds on the limbs. The antiformal structures tend to be well developed and the intervening synforms pinched out. A type 2 interference pattern (Ramsay 1967, p. 525) between F2 and F3 is well illustrated by the outcrop pattern of the Port aux Basques Granite.

The fourth phase of deformation, D4 (basement) is a rather minor phase and is sporadically developed over the entire area. It is characterised by open folding of the gneissic banding and a crenulation which strikes northeast and dips at a relatively shallow angle (30° to 50°) to the northwest.

D1 (basement)

Over most of the area the presence of S1 can only be inferred from the composite nature of S2. It is, however, preserved as inclusion trails within garnet and staurolite porphyroblasts (Plate 13). At Channel Head S1, defined by biotite? is observed to be folded around an F2 fold (Plate 14). Knots of quartz and feldspar, which may represent relict F1 fold hinges, can be traced around F2 fold hinges.

D2 (basement)

D2 (basement) is an intense phase of deformation which results in flat lying isoclinal folds. The associated fabric is parallel to the gneissic banding, and at F2 fold closures any fabric being folded around the core is generally totally transposed parallel to the D2 fabric. Minor F2 folds are uncommon, except in a northeast striking belt which runs inland from the coast in the Port aux Basques to Grand Bay area. These folds are straight limbed irrespective of scale.

Where the minor folds are absent it is generally not possible to differentiate, in the field, the second and third fabrics, since both are parallel to the gneissic banding. Where S3 is observed to cross cut the gneissic banding the D2 fabric is seen to be a composite S tectonite fabric defined by muscovite and biotite.

At F3 fold hinges where the S3 fabric is weakly developed the D2 fabric is well preserved. In the leucocratic bands it is a composite S tectonite defined by fine 2 - 3 mm. wide mica rich bands separated by quartz and feldspar rich bands. In the amphibolites it is an L-S tectonite defined by hornblende and biotite. The hornblende crystals are up to 1 cm. in length and define a lineation. This lineation is folded by D3. A fine 2 - 3 mm. wide segregation banding is also found to be folded around the F3 closures. This banding is parallel to the gneissic banding and consists of hornblende-biotite rich layers separated by plagioclase rich layers.

The large scale D2 structures could not be determined over much of the area due to the intensity of the later deformation and the absence of recognisable marker horizons. However, between Port aux Basques and Foxroost, the distinctive nature of the Port aux Basques Granite allows the mapping of the major F2 folds. The granite occurs as sheets which are folded during D2 and D3 and define a type 3 interference pattern (Ramsay, 1967). The D3 folds are upright. The D2 folds are flat lying, isoclinal folds with an amplitude in the order of 5 km., a wavelength in the order of 1 km. and the axial plane strikes northeast. The folds close to the northwest.

D3 (basement)

The D3 deformation formed tight upright folds which fold the gneissic banding. The axial plane strikes northeast and dips 60° to 80° to the southeast. The folds are generally asymmetrical and are characterised by numerous parasitic folds close to the hinge areas. This feature is present on all scales of F3 folding. The plunge of the folds is highly variable due to interference with the earlier structures (Ramsay, 1967).

In the western part of the gneiss complex the F3 folds are open and do not have a pronounced axial planar fabric. This fabric is defined in the leucocratic bands by muscovite and biotite and overprints or cross cuts S2. In the melanocratic bands an L-S tectonite is developed, defined by hornblende and biotite.

In the central part of the Complex the folds are subisoclinal to isoclinal, and their asymmetric nature becomes pronounced. Minor parasitic folds on these F3 folds show that most are antiformal. These antiforms can be grouped by their asymmetry, into larger antiforms with a wavelength of up to 50 m. These in turn are grouped into antiforms with wavelengths of up to 1.5 km. The associated synforms are subordinate or are completely pinched out, especially in the larger scale structure.

F3 folds with a wavelength of 50 m. or less are easily recognisable in the gneiss. The large scale structure is however difficult to define due mainly to its large dimensions and to the difficulty of recognising the intensely flattened zones which represent the intervening synforms. In the eastern part of the Complex the Port aux Basques Granite shows well the form of the large structure.

In the Port aux Basques ares the S3 has similar characteristics to that in the west except that it is better developed. Where no F3 folds are observed the S2 and S3 fabrics are parallel to the gneissic banding, and cannot be differentiated. The S3 fabric is however observed to cross cut the gneissic banding close to F3 fold hinges.

In the Margaree to the Isle aux Morts area the gneisses are regularly banded and have been intensely flattened in the plane of S3. (Plate 15). The D3 fabric is always concordant with the gneissic banding. The F3 folds are isoclinal and generally do not show the asymmetry noted in the west. Boudinage and incipient boudinage structures become apparent. (Plate 16). There are two sets of these structures, a subvertical set (boudinage axis plunge 70° to 80° to the southwest), and a subhorizontal set (boudinage axis plunge 10° to 20° to the northeast). These structures imply that the k value (Flinn, 1962) is greater than zero but less than unity in this area.

D4 (basement)

D4 is a rather minor phase of deformation which is sparsely developed throughout the area. It is characterised by open monoclinal folds with a poorly developed axial planar fabric. This fabric strikes northeast and dips 30° to 60° to the northwest. A crenulation of the previous fabrics, which is quite well developed, is attributed to this phase of deformation.

The Port aux Basques Granite contains S2 and S3 but does not contain S1. The intrusion of the main body thus post dates the first deformation but predates the second event. The granite sheets are always conformable with the gneissic banding. Pegmatites both cross cut and conform to the gneissic banding and whilst most contain S2 and S3 some only contain S3. Thus although the main intrusive event postdated D1 and predated D2, minor intrusion continued through D2 but ceased prior to the D3 event.

Summary

D1 (basement): Very poorly preserved biotite fabric.

D2 (basement): Intense phase of deformation resulting in flat lying isoclinal folds which strike northeast and close to the northwest. This phase is, in part, responsible for the development of the gneissic banding.

D3 (basement): Upright subisoclinal to isoclinal folds which strike northeast and are slightly overturned to the southeast. This phase deforms the gneissic banding.

D4 (basement): Minor phase resulting in a crenulation of the previous fabrics.

These deformations all predate the deformations which form the reworked zone. They also predate the Cape Ray Fault. Their relationship to the deformations affecting the Cape Ray Complex could not be determined.

Reworked Gneiss

East of Isle aux Morts the Port aux Basques Gneiss Complex has been affected by later deformational episodes. These deformations are named D1 (cover), D2 (cover), and D3 (cover) since they infold, into the gneisses, a sequence of metasedimentary rocks, the Harbour le Cou Group whose deposition and deformation postdate the formation of the Port aux Basques complex. In all three phases the intensity of deformation increases from west to east and related folds change from open in the west to isoclinal in the east. The first phase is the most intense and affects the gneisses as far west as Isle aux Morts. Between Isle aux Morts and Granby Sound it is restricted to narrow shear zones within which the gneissic banding is broken down. East of Granby Sound the gneissic banding is folded into large recumbent antiforms and synforms with axial plane trending northeast and dipping at a shallow angle to the northwest.

Two major and two minor tectonic slides are associated with this phase of deformation. The major slides strike northeast to east northeast, dip at a moderate angle to the northwest, and are conformable to the reconstituted gneissic banding. The northern major slide, termed the Harbour le Cou Slide, is usually a highly micaceous, in part sillimanite bearing, shear zone which separates gneissic basement to the south from cover rocks of the Harbour le Cou Group to the north (Plate 17). The southern major slide, termed the Diamond Cove Slide, is defined by a siliceous black mylonite zone which has been intruded by numerous milky quartz pods and stringers. It separates gneissic basement to the north from gneissic basement with infolded cover rocks, to the south.

The second phase of deformation, folds the gneissic fabrics and the S1 fabric. The axial plane of these folds trends northeast and dips at moderate to steep angles to the northwest. The deformation is not as intense as D1 and is only developed east of the Barasway. However, like the first deformation it increases in intensity eastwards, and in the Rose Blanche area it strongly overprints and partially obliterates the earlier fabrics.

The final phase of deformation to affect the gneisses in this area is an open warping about a north-south axis. This deformation rarely produces an axial planar fabric although a strain slip fabric is locally quite well developed.

Each phase of deformation will be described from west to east to illustrate the progressive nature of these deformations and their effect on the gneisses.

D1 (cover)

Three styles of deformation are associated with the first phase of deformation. These are, from west to east, shear zones, recumbent folding, and tectonic slides. The shear zones affect only basement rocks. The recumbent folding affects both cover and basement rocks. The tectonic slides are close to the basement-cover contact, and in part define the contact.

Shear Zones.

Between Isle aux Morts and Granby Sound D1 (cover) is represented by shear zones (six have been found) which strike northeast to east northeast and dip to the northwest. The dip changes from steep to sub-vertical in the west to moderate angles (approximately 45°) at Granby Sound. Individual zones are up to 10 m. in width, and within them the pre-existing gneissic fabrics are overprinted and completely obliterated by the D1 fabric. This fabric is well developed throughout the shear zones and the margins are sharply defined.

At the margins the first indication of renewed deformation is the presence of small drag folds of the gneissic banding. These indicate over-thrusting southeastwards. The poorly developed axial planar fabric of these folds grades rapidly into a well defined muscovite-sericite fabric. This is the main fabric associated with the development of the shear zones and its development results in a breakdown of the gneissic banding.

Towards the centre of the zones the fabric is defined first by muscovite and biotite and then by muscovite, biotite, and sillimanite. The sillimanite var. fibrolite occurs both as single crystals defining the fabric and in pods, up to 2 cms. in diameter, with the S1 schistosity plane. These pods have a circular to elliptical outline on the schistosity plane.

The gneissic banding can be traced into the margins of the shear zones, where it is isoclinally folded. However, towards the centre of the zones it is only rarely preserved and, where seen, occurs as tightly folded discontinuous slivers. The folds plunge steeply to the northeast.

Between Isle aux Morts and Otter Bay the shear zones occur as discreet, sharply bounded units, and the surrounding gneisses are totally unaffected by this deformation. Garnetiferous leucocratic granite dykes, which intrude and cross cut the gneissic banding, are neither folded nor contain a fabric. East of Otter Bay, although the shear zones are still discreet, sharply bounded units, the surrounding gneisses are variably affected by the deformation. This is best seen at the head of God Bay, where numerous garnetiferous leucocratic granite dykes intrude the gneisses. Some of these dykes are completely unaffected by the deformation, whilst others are openly folded, and still others quite tightly folded.

Movement on the shear zones.

Ramsay and Graham (1970) showed that mineral fabrics developed within and confined to shear zones, reflect the orientation of the finite strain ellipsoid in the shear zone. By measuring variations in the orientation of the developed schistosity across the shear zone they were able to compute the amount of deformation within and the displacement across a shear zone. This method is however only applicable to previously undeformed rocks, or to deformed rocks where the state of strain of the wall rocks is known. It can not, therefore, be used here since the state of strain of the Port aux Basques gneisses is not known.

Beach (1974) had a similar problem with the Laxfordian shear zones in northwest Scotland, i.e., they cut previously deformed rocks. However, he managed to calculate an approximate displacement by measuring:

(a) The movement direction within the shear zone i.e., the intersection of a plane parallel to the margins of the zone with a plane normal to the foliation and containing the lineation.

(b) The orientation of the shear zone.

(c) The orientation of a marker horizon (i.e. dyke) external to the shear zone.

(d) The horizontal displacement of the marker horizon across the shear zone.

This method could not be applied to the shear zones cutting the Port aux Basques Complex due to:

(a) The scarcity of marker horizons.

(b) Where marker horizons are present i.e., garnetiferous leucocratic granite dykes, they can not be traced across the shear zones.

(c) There is no marked lineation.

Several generalised conclusions can however be arrived at concerning the shear zones.

(a) They are a result of an inhomogeneous phase of deformation that is represented, in the west, by discreet highly deformed units and which gradually changes eastwards into a more regional, although still inhomogeneous phase of deformation. Accompanying this change in style the shear zones change in dip from steep to subvertical in the west to moderate angles in the east.

(b) Drag folds at the margins of the zones imply at least some movement across the zones. The asymmetry of these folds indicates that the predominant sense of movement over the entire area is west side upwards i.e., an eastward overthrusting of basement towards cover.

Recumbent Folding.

East of Granby Sound the Port aux Basques gneisses are folded by D1 and the deformation is developed on a regional rather than local scale. The style of the folding is dominantly recumbent isoclinal, closing southeast, with the axial planar fabric striking northeast to east northeast and dipping at a moderate to shallow angle to the northwest. The upper limbs of the antiforms are well preserved whilst the lower limbs, and the intervening synforms are generally sheared out. With increasing intensity of deformation both northeast along strike and southeast across strike, the intervening synforms become tectonic slides. The wavelength of the recumbent antiforms is in the order of 1 km., whilst that of the synforms is generally less than 100 m.

Between Pigeon Island and Tinker Island the folds are upright although still asymmetrical to the southeast. The wavelength of both antiforms and synforms is in the order of 200-300 m. and both limbs are preserved.

D1 is variable from west to east. In the west, at Granby Sound it results in a crenulation of the pre-existing gneissic fabrics. This develops westward into a strain slip fabric with concommitant realighment of the gneissic fabrics. In the east towards Rose Blanche, the gneissic fabrics are almost totally transposed.

This variability of development of S1 throughout the reworked zone makes its description, as a unit, untenable. It is therefore proposed to take serial sections through the reworked zone (Fig. 3) in an attempt to illustrate both the progressive nature of the deformation from west to east, and its changing effect upon the gneisses.

Section 1.

At Granby Sound S1 is concordant with, and grades into, the fabric related to the development of the shear zones. In this area the fabric is axial planar to small asymmetric open folds and is defined by aligned muscovite and biotite flakes. At this stage the fabric is poorly developed and the gneissic fabrics are little affected by its development.

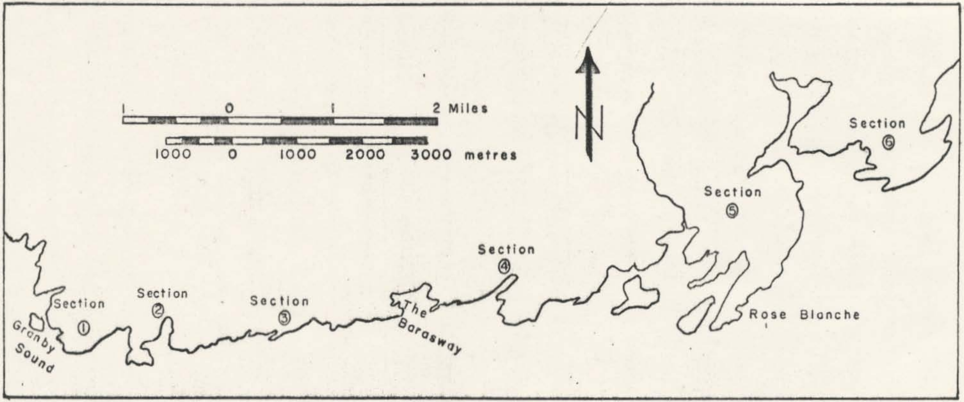
Section 2.

The deformation results in subisoclinal folds with the axial planar fabric crenulating the pre-existing gneissic fabrics (Plate 18). The crenulation is best developed in schistose bands and has a wavelength in the order of 1 cm. The micas are broken rather than folded around the fold hinges (Plate 19). In the basic bands the micas are also broken and

Figure 3

Localities of Sections used in the Description

of the Reworked Zone



1 0 1 2 Miles
1000 0 1000 2000 3000 metres
N
Section ⑥
Section ⑤
Section ④
Section ①
Section ②
Section ③
Granby Sound
The Barasway
Rose Blanche

the trace of these crenulations forms 'augen' around garnet porphyroblasts (Plate 20). In quartzo-feldspathic bands D1 is characterised by isoclinal folding and an axial planar fabric is well developed. This fabric transposes and realigns the earlier gneissic fabrics (Plate 21).

Leucocratic garnetiferous granite dykes are common in this area and are folded and boudinaged by the D1 deformation (Plate 22). Those dykes which strike east northeast and dip to the northwest are folded whilst those which strike north-south are boudinaged. One dyke striking 010° and dipping 50° west, although containing S1, was neither folded nor boudinaged.

The orientation, and style of deformation, of these dykes is used to set limits on the orientation of the D1 strain ellipsoid (Flinn, 1962; Talbot, 1970) at this locality. Of particular importance, in this respect, is the dyke which is neither folded nor boudined by D1 since it defines the surface of no finite longitudinal strain (Talbot, 1970) and separates areas of compressive and extensional tectonics.

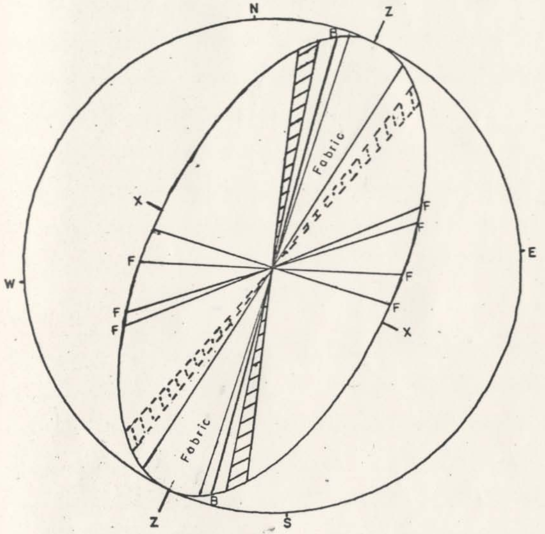
Although insufficient data is available to give an exact representation of the D1 strain ellipsoid, an approximation can be arrived at (Fig. 4). The Z axis ($Z > Y > X$) strikes 040°. The ZY plane dips 70° northeast, and the Z : X ratio is in the order of 3 : 1.

Section 3.

D1 here results in isoclinal to subisoclinal folds of the gneissic banding (Plate 23). The composite style of fabric of the gneissic banding is still evident and can be observed to be folded around the hinges of these folds. At the fold hinges the micas defining the composite gneissic fabric, are completely reorientated parallel to S1 (Plate 24).

Figure 4

Orientation of the Deformation Ellipsoid in Section 2 of the Reworked Zone. B - Boudinaged Dyke; F - Folded Dyke; /F/ - Dyke neither Folded nor Boudinaged


N
Z
B
Fabric
X
F
F
F
F
E
W
F
F
F
X
Fabric
Z
B
S

On the fold limbs S1 is either parallel or sub-parallel to the composite gneissic fabric.

Where the gneissic banding is not coarsely schistose the D1 fabric is observed to break down the early composite style of fabric, and a finely schistose, rather than banded rock is developed. Basic bands are not present in the gneisses in this area.

Garnetiferous leucocratic garnet dykes are locally abundant. They are generally intensely flattened in the plane of S1 and their original orientation could not be determined. No interpretation of the orientation of the strain ellipsoid was thus possible in this area.

Section 4.

S1 is the main fabric observed in the gneisses, although the composite gneissic fabric can still locally be seen to be folded around the F1 fold hinges. The micas defining the composite fabric are totally transposed and realigned parallel to S1. Where the composite banding has been folded into parallelism with the D1 fabric it is preserved. However where there is a discordance between the two structures the composite fabric tends to lose its continuity. This is especially noticeable in the garnet - quartz bands. These bands, which are common in the gneisses here, are continuous in the former case, but in the latter they are broken up and form small boudinage structures.

The basic bands in the gneiss have been boudinaged and occur as isolated pods (Plate 4). The dominant fabric within them is S1. Calc - silicate bands are quite common here and contain a compositional banding which is parallel to the D1 fabric.

Garnetiferous leucocratic granite dykes are intensely flattened in the plane of D1. Where the composite fabric is at an angle to S1, the cross cutting relationship of the dykes is still observable. However, where the D1 fabric and the composite fabric are parallel the dykes are rotated into the plane of the banding and the original cross-cutting relationship obscured.

Section 5

The compositional banding of the gneisses in this section is almost always parallel to S1 and F1 folds are not observed. The compositional banding now comprises the original composite gneissic banding plus the D1 fabric. Pods of well banded-amphibolite gneiss, similar to the Port aux Basques gneiss prior to the reworking, are found close to the contact of the Rose Blanche Granite at Rose Blanche. The reconstituted gneiss fabric forms augen around these gneissic pods and it is suggested that they are large boudin-like structures which, although flattened within the plane of S1, have not been reconstituted with the rest of the gneiss in this area.

Garnetiferous leucocratic granite dykes are quite common here and are intensely flattened in the plane of S1 such that their cross cutting relationships with the composite banding is usually obliterated. (Plate 25).

Section 6

East of Rose Blanche the intensity of D1 appears to decrease and F1 folds are locally observed. In the extreme east of the area, at Garia Bay, the gneisses are quite intensely flattened by this phase of deformation but they are not reconstituted. The presence of S1 is shown by garnetiferous leucocratic granite dykes which cross out the gneissic fabric and are folded by and contain a fabric related to this deformation.

Slide Zones.

Two major zones of intense flattening are present in the reworked gneiss. The northern of the two extends from northeast of White Head in the west to east of Harbour le Cou. The southern zone extends from Mull Face Bay in the west to Bay le Moine in the east. The position and development of these zones is structurally controlled in that both are developed during D1, and are conformable with S1. Furthermore, the northern zone can be traced into the lower limb of a recumbent antiform. The zones are therefore termed slides (Fleuty, 1964). Although actual displacement could only be shown on the southern zone.

The northern slide, the Harbour le Cou Slide, strikes northeast to east, dips 40° - 70° northwest to north, and has a variable character along its length. In the west at White Head, the slide is represented by the lower limb of a recumbent antiform. There is no distinct discontinuity around the core of the antiform and underlying synform, although the D1 fabric, which is axial planar to these folds, in part transposes the gneissic fabrics (Plate 26). Approximately 1 km. along strike to the northeast no change in vergence (S1 with respect to the more composite gneissic fabric) was found across the slide, implying either that the folds at White Head are minor and have died out or that the lower limb of the antiform is not present. The latter is thought to be the more likely since the gneisses are more highly deformed here and an intensely flattened quartz rich rock containing a tectonic banding is found where the lower limb of the antiform should be. A further kilometer along strike a complete section across the slide is exposed at a road cut (Plate 17). Gneisses occur on the southern side of the slide and contain a composite fabric in part transposed by D1. The slide itself is a quartz-rich mica-poor rock, upwards of 5 m. thick, containing abundant quartz pods and stringers. The rocks on the northern side of the slide do not contain a fabric earlier than D1, which here is parallel to the slide zone. ~~These~~ rocks, therefore, belong to the Harbour le Cou Group and the slide separates, at this locality, basement rocks to the south from cover rocks to the north.

The slide can be traced from this locality to east of Harbour le Cou, and appears always to separate basement to the south from cover to the north, although total transposition of the early gneissic fabrics makes it extremely difficult to distinguish the two rock types. Although generally a quartz-rich mica-poor rock with abundant milky quartz pods and stringers, east of Rose Blanche Brook the slide is defined by a thin sericitic-graphitic schist with sharp boundaries.

The southern slide, the Diamond Cove Slide, extends from Mull Face Bay in the west to Bay le Moine in the east, strikes north east to east, dips 30° – 60° to the north west to north, and is much wider and better developed than the northern slide. It cannot definitely be traced back to the lower limb of a recumbent antiform although vergence at Mull Face Bay suggests this structural position. In the west the slide is a black, quartz rich, mica poor rock with abundant milky quartz pods. The largest of these pods, at Diamond Cove is 100 m. in length and 30 m. wide. A mylonite banding is developed parallel to the length of the zone. Basement rocks occur on both sides of the slide.

East of Rose Blanche the slide changes character in that the number of milky quartz pods and stringers is greatly reduced. Basement rocks occur to the north of the slide. Basement and cover rocks are present to the south. There is, however, usually a sliver of basement between the slide and the cover rocks. The slide is, therefore, restricted to basement rocks over most of its length.

Several garnetiferous leucocratic granite dykes are cut off by the slide at Mull Face Bay, Diamond Cove, and Rose Blanche. Unfortunately no correlation of these dykes, across the slide was possible. Therefore although there has definitely been movement along the slide, the magnitude of the movement could not be computed.

A third slide, the Rose Blanche Slide, crops out on Duck Island, Hopkins Island and north of Rose Blanche. In the southeast it is lithologically similar to the Diamond Cove Slide and is confined to basement rocks. North of Rose Blanche the slide is a narrow, poorly defined quartz rich rock with sparse milky quartz pods. In this area it is thought to separate basement rocks to the south from cover rocks to the north, although the total transposition of the gneissic fabrics here makes identification of basement from cover rocks exceedingly difficult.

It is found on the eastern side of Harbour le Cou Bay and can be traced to Bay le Moine. In this area it separates cover rocks to the north from basement rocks to the south.

Two minor slides define the northern limit of both slivers of cover rocks. These slides are only recognised in the Harbour le Cou - Rose Blanche area and could not be traced along strike in either direction for any great distance.

D2 (cover)

This phase of deformation is neither as extensive and only locally as penetrative as D1. It is first observed at the Barasway, where minor open folds fold isoclinal F1 (cover) folds of the gneissic banding (Plate 27). The associated axial planar fabric strikes northeast and dips 60° to 70° to the northwest, and is defined by orientated muscovite and biotite flakes. Between the Barasway and Rose Blanche Brook, although S2 is well developed, minor F2 folds are scarce. The intersection between S2 and S1 indicate that no major D2 folds occur in this area.

In the Diamond Cove - Rose Blanche area minor F2 folds are quite common. In this area D1 has effectively transposed the gneissic banding and D2 folds the resultant composite fabric. The D2 deformation is inhomogeneous and the earlier fabrics may be either totally transposed or merely openly folded (Plate 28). This inhomogeneity is more pronounced across rather than along strike.

East of Rose Blanche the overall intensity of D2 increases such that the D1 composite fabric is generally transposed by D2. On the east side of Harbour le Cou Bay subisoclinal folds are outlined by garnetiferous leucocratic granite dykes (Plate 29), and on the fold limbs S2 is parallel to S1. The slide zones, which are folded by this phase of deformation show the transposition of S1 by the D2 deformation.

To the north of Garia Bay D2 subisoclinally folds the D1 and gneissic fabrics. There is however no reconstitution of the earlier fabrics.

D3 (cover)

This is a minor phase of deformation which results in an open warping of the earlier fabrics about a north-south axis. North of Mull Face Bay a crenulation, associated with the warping, dips 70° to 80° to the west (Plate 30). The only major structure developed is an open antiform between Harbour le Cou and Bay le Moine. In the Diamond Cove – Rose Blanche area box folds are developed. Two fabrics are present, one dipping steeply to the east and the other steeply to the west. These latter are easily confused with the open D2 folds but can be distinguished by the poor development of an axial planar fabric in the later structure.

Summary

Between Isle aux Morts and Garia Bay the Port aux Basques Gneiss has been farther deformed three times. These deformations overprint the basement structures previously described.

D1 (cover): Inhomogeneous phase of deformation developed east of Isle aux Morts. In the west it is represented by shear zones. These become more regional in effect and recumbent folds are developed east of Granby Sound. Slide zones are related to the lower limbs of these recumbent folds. The gneissic fabrics are transposed by this phase of deformation.

D2 (cover): Inhomogeneous phase of deformation developed east of the Barasway. Transposes the D1 fabric and becomes, at Rose Blanche, the dominant phase of deformation.

D3 (cover): Minor phase resulting in an open warping and box folds. Poorly developed axial planar fabric.

Harbour le Cou Group

The Harbour le Cou Group is a series of cover rocks which are infolded with the basement rocks of the Port aux Basques Complex. Two slivers of this Group are defined. The northern sliver crops out to the north of the Harbour le Cou Slide, and extends from north of the Barasway to east of Harbour le Cou. The southern limit is defined by a tectonic slide against basement rocks. The northern boundary could not be accurately defined in the western part of the area, but east of Harbour le Cou it is seen to be in fault (slide ?) contact with basement rocks to the north. The southern sliver crops out between the Diamond Cove Slide and the Rose Blanche Granite, and extends from Rose Blanche to Bay le Moine. The northern and southern limits of this sliver could not be clearly defined but appear to be slide zones.

The Group has been deformed and metamorphosed three times. These deformations affect the Port aux Basques Complex and give rise to the reworked zone. Unlike the gneisses however these rocks show no evidence of earlier deformational or metamorphic events. Unfortunately no definite sedimentary structures were observed. The differentiation of the Harbour le Cou Group and the reworked zone thus falls back on the intrusive relationships of the Rose Blanche Granite i.e., in the reworked zone the granite intrudes a rock which contains a composite tectonic fabric. This early composite fabric is nowhere observed in the rocks defined as the Harbour le Cou Group.

These deformations are therefore named D1 (cover), D2 (cover), D3 (cover) since they are the first deformational events to affect these rocks.

D1 (cover)

This deformation is developed throughout the Harbour le Cou Group.

Although best developed in the east it is best preserved in the west due to the overprinting effects of later deformations. The orientation of the fabric is variable due to the later deformations but the dip is generally less than that of the D2 fabric.

North of the Barasway SI is defined by orientated biotite laths, which are parallel to a compositional banding i.e., biotite rich zones and biotite poor, quartz rich zones. These bands are highly variable in both width and composition (Plate 31). The quartz rich bands, which may be up to 5 cms. in width generally contain less that 5% mica. These either grade into or have a sharp contact with bands containing up to 15% biotite. The biotite rich bands (greater than 15% biotite) are less than 1 cm. in width, have sharp boundaries against the quartz rich bands but show a gradation into the bands containing 5 - 15% biotite. This gradation is also well shown by the distribution of garnet.

The variations in composition described above are similar to that of graded bedding in semipelites i.e., quartz rich base grading up into quartz-biotite and finally to a biotite rich top. This would be followed by the quartz rich base of the next bed, and the contact between the two would be sharp. It should also be noted that this banding is totally dissimilar to a tectonically produced banding in that the latter is generally very regular with individual bands being in the order of 2 - 3 mm. and with sharp compositional changes at both sides of the bands and little or no compositional gradation within bands. It is therefore proposed that although the texture of the rock is now metamorphic, the variations described above reflect original sedimentary features. No definite banding--D1 (cover) intersections were observed and hence the D1 structures could not be determined within the Harbour le Cou Group.

Approximately 100 m. west of Rose Blanche Brook the compositional banding described above is seen to change character and is now defined by biotite-garnet bands up to 5 mm. in width which are sharply bounded against quartz rich biotite poor bands up to 2 cms. in width (Plate 32). The D1 fabric is effectively transposed by D2 here and its orientation and characteristics could not be determined. East of Rose Blanche Brook the later fabric is dominant but S1, defined by muscovite and biotite flakes can still be seen within the S2 schistosity planes.

At Harbour le Cou, and on the east side of Harbour le Cou Bay the Group consists of pelites. In this area S2 is the main fabric, and S1 is only locally observed in fine quartz rich bands (Plate 33). Close to the Diamond Cove slide the second fabric forms augen around pods of muscovite. These locally show a well developed internal fabric. This fabric is a remnant of S1.

The southern sliver of the Harbour le Cou Group extends from Rose Blanche to Bay le Moine and over its length S2 is the dominant fabric. Pods of muscovite, similar to these found at Harbour le Cou, are found and these contain an internal fabric, i.e., S1. On the east side of Harbour le Cou Bay S1 is locally observed as single flakes of mica between the S2 schistosity planes.

D2 (cover)

This deformation is present throughout the entire Harbour le Cou Group and increases in intensity from west to east. North of the Barasway D2 folds bedding? and S1, and a fine fabric defined by muscovite and biotite flakes is developed. At the fold cores S1 is in part transposed.

The fabric strikes northeast and dips 40° to 70° to the north west.

Approximately 100 m. west of Rose Blanche Brook S2 becomes the dominant fabric in the rock. It is defined by the coarse development of muscovite and biotite the earlier fabric is transposed (Plate 32). East of the Rose Blanche Brook the transposition of S1 results in the development of a composite fabric. S1 is now only preserved as individual mica flakes between the S2 schistosity planes. (Plate 33).

Between the Barasway and the Rose Blanche Brook the intersection, between S1 and S2 indicate that no major D2 folds occur in this area. Minor folds are uncommon, but where found are observed to be sub isoclinal (Plate 32). In the Rose Blanche - Harbour le Cou to Bay le Moine area the D2 folding, as shown by the garnetiferous leucocratic granite dykes, is sub-isoclinal to isoclinal.

In the Rose Blanche - Harbour le Cou to Bay le Moine area the D2 fabric is defined by a composite banding. This banding is totally dissimilar to the compositional banding found north of the Barasway in that it is tectonic in origin rather than an original sedimentary feature. It has resulted from a segregation of mica and quartz during the transposition of S1 by the D2 deformation. (Plate 34). The banding is defined by mica rich bands, up to 3 mm. across, separated by quartz rich bands up to 5 mm. across. There is no compositional gradation across the bands and the contacts on both sides are sharp. This banding forms augen around mica porphyroblasts which contain the D1 fabric.

On the west side of Harbour le Cou Bay the composite banding is very well developed. In this area the mica poor bands are defined by garnet and quartz. The composite fabric forms augen around these garnets and S1 can locally be observed between the S2 schistosity planes. Where the rock is highly micaceous D2 results in a reorientation of the mica laths, but no composite banding is developed.

D3 (cover)

Although prevalent throughout the Harbour le Cou Group, D3 is a minor phase of deformation. It results in an open warping of the previous fabrics about a north-south axis. The only major fold associated with this phase is an antiformal structure on the east side of Harbour le Cou Bay. The related axial planar fabric is poorly developed, strikes north, and dips 70° to 80° both to the east and west, although generally to the west. Box folds are developed close to the Rose Blanche granite.

North of Mull Face Bay, where the rocks are semipelitic, the S3 is poorly developed. However, in the Harbour le Cou area, where the rocks are semi-pelitic, S3 is much better developed, and is defined by parallel to subparallel pelitic strain bands (Dewey, 1969).

Summary

D1 (cover): First deformation to affect the Harbour le Cou Group of sediments. Largely overprinted by D2.

D2 (cover): Not as penetrative as the first deformation. Increases in intensity from west to east, and, in the east totally transposes the earlier D1 fabric.

D3 (cover): Minor phase of deformation resulting in kinking and crenulation of the previous fabrics.

Bay du Nord Group

The Bay du Nord Group has been deformed and metamorphosed three times. The first phase is poorly preserved and is generally almost completely transposed by the later deformations. The second phase is the main phase of deformation in the area and results in upright isoclinal folds which strike northeast. The axial planar fabric associated with these folds is vertical to sub-vertical and is generally parallel to bedding features, where these are preserved. No definite F2 fold closures are observed. Where "way up" criteria i.e., graded and cross bedding, are observed the F2 structures are predominantly downward facing with respect to the bedding. The third deformation crenulates the earlier fabrics and where a D3 fabric is developed it strikes north northeast and is subvertical.

D1 (cover)

The first phase of deformation is variably developed and variably preserved over the area. In the west the fabric is well developed, is parallel to the bedding, and is almost totally transposed by the later deformations. In the east S1 is quite well preserved between the S2 schistosity planes.

The lack of any S1-bedding intersection data makes any interpretation of possible D1 facing directions untenable. However the succession is predominantly downward facing on the upright D2 cleavage, indicating that D1 folding has resulted in large scale recumbent folds and that the succession here is structurally positioned on the lower limb of a recumbent antiform.

D2 (cover)

The second phase of deformation produces the dominant fabric in the Bay du Nord Group. The fabric strikes northeast, and dips vertically or sub-vertically and is generally parallel or subparallel to bedding features. No fold closures, associated with this phase of deformation were observed. However rapid changes in "way up" criteria in subvertical beds suggests tight isoclinal folds. Elongated quartz pods indicate a steep plunge for the second structures.

The development of the D2 structures and associated axial planar fabric is variable over the area. In the east the folds are sub isoclinal and the axial planar fabric is poorly developed. To the west the folds become isoclinal and the fabric transposes and completely obliterates the earlier D1 fabric. In the Bay de Moine area a composite D2 fabric is observed.

D3 (cover)

The third phase of deformation is defined by a poorly developed strain slip fabric which strikes north to north northeast, and has a vertical to subvertical dip. Kink bands are associated with this phase of deformation. These tend to be reverse (Dewey, 1969) and locally show a complex internal structure, i.e., double and triple kinks.

The S2 - S3 intersection is consistent over the area and implies an antiform to the east. Such an antiform was proposed by Cooper (1954) for the Bay du Nord Group in the La Poile area.

Summary

D1 (cover): Large scale recumbent folds.

D2 (cover): Tight upright folds. The earlier fabric is largely transposed by this event.

D3 (cover): Minor phase of deformation resulting in kinking and a crenulation of the previous fabrics.

Windsor Point Group

The sedimentary and volcanic rocks of the Windsor Point Group have been deformed three times. These deformations, termed D1 (cover), D2 (cover), and D3 (cover), are the first deformations to affect the Group, and all appear to be related to the Cape Ray Fault, since they increase in intensity toward, and can be traced into, the fault zone.

D1 (cover)

This deformation affects the entire Windsor Point Group and shows a marked increase in intensity toward the Cape Ray fault. The fabric strikes northeast and dips at a high angle to the southeast. Close to the fault a fine 2 - 3 mm. wide tectonic banding, defined by mafic and felsic rich layers, is developed. In the conglomerate this banding forms augen around the pebbles (Plate 8). The pebbles are intensely flattened in the plane of the D1 fabric.

Away from the fault zone the D1 fabric is defined by a cleavage. This cleavage is axial planar to open F1 folds. These folds are well illustrated by thin conglomerate beds within the tuffaceous sequence.

D2 (cover)

The second phase of deformation is similar to, and coaxial with, but less intense than D1. Close to the fault zone D2 sub isoclinally folds the D1 banding. An axial planar fabric, defined by chlorite and sericite, is quite well developed.

The effects of this deformation die out rapidly away from the fault. However, a penetrative cleavage is locally developed. This is parallel or subparallel to the D1 cleavage.

D3 (cover)

D3 is a minor phase of deformation which results in the formation of kink bands. Conjugate folds are developed close to the fault zone. The kink planes strike north northeast and east southeast and generally dip steeply to the east. All observed kink bands are normal (Dewey, 1969).

Summary

D1 (cover): Intense close to the Cape Ray Fault resulting in the development of a tectonic banding, but is generally represented by a penetrative cleavage.

D2 (cover): Isoclinally folds the D1 (cover) banding close to the fault. A penetrative cleavage is developed for some distance away from the fault.

D3 (cover): Minor phase resulting in conjugate folds and kinks.

These deformations only affect the Windsor Point Group and are related to late movements on the Cape Ray Fault. They post date the deformations affecting the Port aux Basques Complex, the Cape Ray Complex, and the formation of the Cape Ray mylonite zone.

Faults

Within the study area there are only two faults which have more than minor local importance. These are, the Cape Ray Fault Zone, in the extreme west of the area, and the Bay le Moine Fault in the extreme east of the area.

Cape Ray Fault

The Cape Ray Fault Zone separates the Port aux Basques Complex to the east from the Cape Ray Complex to the west, and is in part overlain by the Windsor Point Group. It is defined by a zone of intense flattening or shearing, up to 100 m. wide, and crops out on the coast 200 m. east of Windsor Point. Zones of intense deformation, associated with the fault, are observed up to 4 km. across strike on either side of the fault. These minor zones are usually less than 20 m. wide, and within them the pre-existing gneissic fabrics are totally obliterated.

The main fault zone is defined by a mylonite (Harker, 1950; Christie, 1960; Higgins, 1971), and several phases of movement can be determined. The earliest, and most important, event was the development of the mylonite banding, with concommitant breakdown of the previous fabrics in the gneiss complexes. The banding is generally less than 5 mm. in width and defined by quartz-feldspar rich bands separated by chlorite-epidote-biotite rich bands. No relict gneissic fragments were found within the main fault zone.

Prior to the later phases of movement the Windsor Point Group was deposited upon the mylonite zone. Three later deformational episodes are

:ognised. These are related to the deformations which affect the indsor Point Group and are therefore termed D1 (cover), D2 (cover), 3 (cover). The earliest, D1, resulted in isoclinal to sub-isoclinal olding of the mylonite banding and on the fold limbs, the new fabric, defined by chlorite and biotite, is parallel to the banding. At the fold cores partial transposition of the banding has occurred. These folds plunge steeply northeast.

The second phase results in tight to open folds of the isoclinally folded banding, and a weak axial planar fabric, defined by chlorite and biotite, developed (Plate 35). The folds plunge steeply to the northeast. The final phase is minor and results in box folding and kink bands. The axial plane of these minor structures strikes east-west and dips both north and south.

Summary.

Formation of mylonite banding.

D1 (cover): Isoclinal folding of the mylonite banding.

D2 (cover): Tight to open folds of the folded mylonite banding.

D3 (cover): Box folds and kink band formation.

Bay le Moine Fault

The Bay le Moine fault extends from Bay le Moine through to Garia Bay. The fault plane strikes northeast, dips to the southeast, and is defined by a fracture zone. In Bay le Moine it separates the Rose Blanche Granite and reworked Port aux Basques Gneiss and Harbour le Cou Group to the northwest, from the Petites Granite and Bay du Nord Group to the southeast. At the head of Bay le Moine the Petites Granite is found on both sides of the fault. At Garia Bay the fault separates the reworked Port aux Basques Gneiss to the northwest from the Bay du Nord Group to the southeast.

The effects of the fault are best seen within the Petites Granite, where a fracture system is developed. Two sets of fractures are observed, a northeast-southwest and a northwest-southeast striking set. These are filled with milky quartz and locally molybdonite is abundant. Close to the fault the granite is broken down along these fractures, to a fine chlorite-sericite quartz rock. Away from the fault the fractures become widely spaced and no breakdown of the granite was observed.

The predominance of basement rocks and the scarcity of cover rocks to the northwest of the fault, the lack of basement rocks and the predominance of cover rocks to the southeast of the fault, and the presence of the Petites Granite on both sides of the fault indicates that the fault is most probably dip slip, with the downthrow side to the southeast.

CHAPTER 7

METAMORPHIC HISTORY

The metamorphic history is described in terms of mineral growth stages which are identified with reference to periods of deformation. These mineral growth stages are referred to as MS1, MP1, MS2, etc. after Sturt and Harris (1961), and represent essentially an alternating sequence of dynamic and static growth stages (Zwart, 1960, 1962, Rast, 1965; Spry 1969). While it is realised that this is essentially a continuous sequence of events, the development of preferred mineral orientation during periods of dynamic or syntectonic growth (Flinn 1965) provides recognisable markers in the sequence which are used for a descriptive subdivision.

In the previous chapter the subscript basement or cover was used to differentiate between deformations which affected only basement rocks from those which affected only cover or basement and cover rocks. This chapter follows closely the outlines of the previous chapter and since the distinction i.e., basement or cover, has already been determined, these subscripts will not be used here. Thus, under the subheading Port aux Basques Complex, MS2 refers to the syntectonic growth episode related to D2 (basement) of the Port aux Basques Gneiss. Under the subheading Harbour le Cou Group, MS2 refers to the syntectonic episode related to D2 (cover) of that Group.

Cape Ray Complex

The Cape Ray Complex has been deformed at least three times. The metamorphic growth stages related to these deformations are however masked by a late retrogressive phase of metamorphism. The retrogression is best developed close to the Cape Ray Fault and appears to be related to early movements on the fault.

Pre D2 (basement)

The evidence for pre D2 metamorphic events is contained within basic pods which occur in the Long Range Gneiss. These pods contain a banded fabric and the D2 fabric forms augen around them. The banding is 2-3mm. wide and defined by hornblende - biotite rich and plagioclase rich bands. The mafic bands are largely retrogressed to chlorite and epidote, and the felsic bands to sericite.

The leucocratic Long Range Gneiss does not show pre D2 fabrics.

MS2

Within the Long Range Gneiss quartz and feldspar crystals are granulated and a mortar texture developed. Quartz porphyroblasts show pull apart structures with the cross fractures defined by polygonised quartz. (Plate 36). Plagioclase is variably altered to sericite and epidote. Biotite is altered to chlorite.

Within the plane of the mortar texture biotite and quartz locally show a vermicular intergrowth. This growth is largely controlled by the (001) plane of biotite (Kretz, 1966; Vernon, 1968) and results in a fine banding of the two minerals. The banding is parallel to, and in part defines the D2 fabric.

Table 2

Structural and metamorphic history of the Cape Ray Complex from Red Rocks to the Cape Ray Fault

W → E W → E

	Structure	Metamorphism		Intrusives
				Red Rocks Granite
		MP3	ser, calc.	
D3	Inhomogeneous flattening	MS3	SER, CALC.	
		MP2	bi, chl, ep.	
D2	?	MS2	BI, CHL, EP.	Cape Ray Granite
		MP1	?	
D1	?	MS1	HB, BI.	
Pre D1 history ?				

TIME

CHL. - chlorite, CALC. - calcite, SER. - sericite

EP. - epidote, HB. - hornblende

CHL - growth of the mineral i.e., chlorite

chl - recrystallisation of the mineral i.e., chlorite

MP2

The granulated quartz and feldspar defining the mortar texture is recrystallised to form polygonal aggregates. The recrystallisation is largely controlled by the (001) plane of biotite and biotite - quartz grain boundaries are straight.

MS3

Continued breakdown of plagioclase to ~~sericite~~ and calcite during the third deformation has produced a mica fabric. (Plate 37). This is very well developed close to the Cape Ray fault and here the rock consists of quartz porphyroblasts and polygonal quartz aggregates, around which the sericite-muscovite fabric forms augen. MP2 polygonal quartz aggregates are locally preserved in the pressure shadows of the quartz porphyroblasts.

MP3

The calcite which was deformed into pods and stringers during D3 has recrystallised into polygonal aggregates.

Port aux Basques Complex

Four episodes of deformation have been recognised in the Port aux Basques Complex. Of these, the metamorphism associated with the second episode is dominant throughout the area. In this phase the highest grade is attained and the previous growth phases largely overprinted.

MS1

Mineral growth attributable to MS1 is generally only recognised as inclusions within MP1 porphyroblasts. They are rare due to the overprinting by later deformational and metamorphic effects. The growth of quartz, feldspar, biotite and magnetite occurs and defines the S1 schistosity. Within MP1 porphyroblasts these minerals define straight inclusion trails.

MP1

Garnet and staurolite are the only minerals forming MP1 porphyroblasts. The S2 fabric forms augen around these porphyroblasts. Where they contain inclusions these define straight trails which are discontinuous with the S2 schistosity (Plate 38). No curved trails were noted.

MS2

The tectonite fabric developed during the MS2 event, although modified by MP2 polygonisation and porphyroblast growth, and partially transposed during the MS3 event, is the dominant fabric in the Port aux Basques Gneiss. It is a composite fabric (Whitten, 1966; Rast, 1966) formed by transposition and regrowth of previous fabrics. In the leucocratic bands it is defined by fine mica rich and quartz-feldspar rich layers. In the melanocratic bands it is defined by hornblende-biotite rich and plagioclase rich layers.

The muscovite and biotite crystals which define S2 occur as orientated laths, generally less than 5mm. in length. They do not contain inclusions. Hornblende usually occurs as euhedral inclusion free crystals. Porphyroblastic MS2 hornblende growth is locally recorded. These crystals are poikiloblastic and contain rounded inclusions of quartz and feldspar.

Staurolite continued growth from MP1 through MS2 times. The quartz and feldspar inclusions within these porphyroblasts show curved inclusion trails which are continuous with the external schistosity (Plate 38). MS2 garnet growth is usually surrounded by an inclusion free MP2 growth rim. Curved inclusion trails are continuous, by extrapolation, with the external schistosity. Quartz and feldspar define these trails.

Kyanite occurs as acicular crystals which define, with mica, the second fabric (Plate 39). These laths are generally poikiloblastic and contain rounded inclusions of quartz and feldspar. Inclusions of garnet are locally observed. Sillimanite var. fibrolite occurs as felted masses which help define S2. These masses are associated with muscovite porphyroblasts. Potassium feldspar (microcline) has grown as a metamorphic mineral in the migmatite zone to the east of Isle aux Morts.

MP2

Most of the minerals that grew during the second deformation continued growth into MP2 times and the boundary between the two growth phases is regarded as being represented by the polygonisation of quartz and feldspar and the mimetic growth of mica. The continued growth of kyanite resulted in large porphyroblastic crystals some of which are euhedral and inclusion free whilst others are poikiloblastic. The former are usually twinned whilst the latter are untwinned. Quartz, feldspar and magnetite inclusions are common. Garnet and staurolite inclusions are rare. Quartz inclusions containing inclusions of staurolite were also observed (Plate 40). The poikiloblastic crystals appear to have started growth during MS2 times since they are generally aligned parallel to the S2 fabric. The inclusion free crystals however, grow across S2 and represent an MP2 event.

Garnet growth continued throughout this period but at a slower rate (Rast, 1965), resulting in inclusion free rims around almost all the MS2 garnet crystals. MP1 staurolite has recrystallised in situ, resulting in a staurolite-polygonal quartz intergrowth, around which S2 forms augen (Plate 41). Elsewhere the MS2 staurolite growth has continued through into MP2 times and has outlasted the MP2 garnet growth.

Where sillimanite and kyanite occur together they either co-exist (Plate 42) or kyanite shows alteration to sillimanite (Plate 43). The fibrolite usually occurs in association with porphyroblastic white mica. It could not be determined whether the white mica has replaced the fibrolite or whether the fibrolite has overgrown the white mica porphyroblasts. However, at least some of the white mica growth is MP2 since the crystals partially overgrow the second fabric. Both fibrolite and white mica are pre D3 since S3 forms augen around these crystals.

<u>MS3</u>

The grade of this phase of metamorphism is highly variable across the area but is more progressive in the east than the west. The growth of quartz, feldspar (An 20-30), muscovite, biotite and hornblende define the S3 tectonite fabric. In the west garnet and plagioclase are slightly retrogressed, at the F3 fold hinges, to chlorite and sericite respectively. Around Port aux Basques and eastwards, MS3 is a progressive event, with the growth of garnet and the recrystallisation of kyanite. Garnet nucleation and growth occurs in thin quartz rich bands. The crystals are pink, less than 0.5mm. in diameter and occur at quartz and feldspar grain boundaries and as inclusions within these minerals.

The kyanite defining S2 is folded during D3 and the crystals are strained and partially altered, at the rims, to fine white mica. Sillimanite var. fibrolite is found in one D3 shear zone. It is not known whether it nucleated and grew during D3, or whether it is reorientated MS2 - MP2 sillimanite.

In the Isle aux Morts area microcline has grown on the limbs of F3 isoclinal folds and partially recrystallised in the hinge areas.

MP3

There was little nucleation and growth during this period of metamorphism. Quartz, feldspar, hornblende, epidote and mica partially polygonised. Kyanite, which was strained in the F3 fold hinges, polygonised (Plate 44) and porphyroblasts partially recrystallised to give smaller crystals which have a different orientation than the parent crystal. The polygonisation of quartz in the garnet-quartz bands was accompanied by continued nucleation and growth of garnet (Plate 45).

MS4

This phase of metamorphism is generally retrogressive. Garnet and biotite are altered to chlorite, especially at the F4 fold hinges.

Quartz, feldspar and mica locally recrystallised, the latter defining a weak axial planar fabric to F4 folds.

MP4

No nucleation and growth of new mineral phases is attributable to this period of metamorphism. Quartz, feldspar and mica are locally polygonised. The MS4 alteration of garnet and biotite continued into this period.

Metamorphic Assemblages

Of the metamorphic events described above the MS2 and MP2 phases are by far the most significant, in terms of distinctive metamorphic assemblages. These assemblages, defined within leucocratic bands, show a metamorphic zonation towards the Port aux Basques Granite and migmatite zone. The assemblages are grouped into zones (Fig. 5) after Brown (1972).

Zone A:

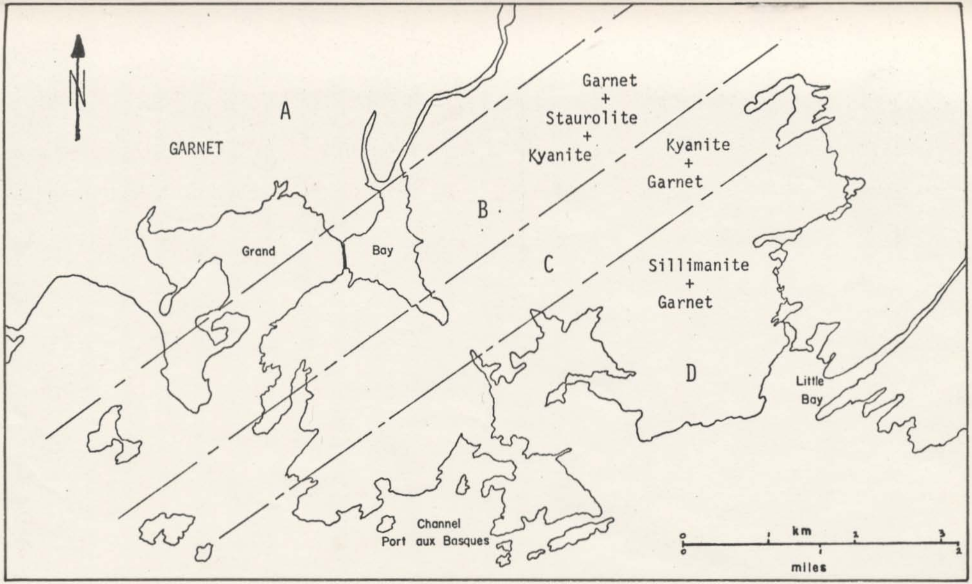
garnet - muscovite - biotite
garnet - biotite
garnet - muscovite +quartz and plagioclase (An. 20-30)
muscovite - biotite

Zone B:

garnet - staurolite - kyanite - muscovite - biotite
garnet - staurolite - muscovite - biotite
garnet - kyanite - muscovite - biotite
garnet - biotite +quartz and plagioclase (An. 20-30)
muscovite - biotite

Figure 5

Metamorphic Zones in the Port aux Basques Area. The Minerals defining these Zones are MS2 to MP2 in Age


N
A
GARNET
Garnet
+
Staurolite
+
Kyanite
Kyanite
+
Garnet
B
C
Sillimanite
+
Garnet
D
Grand
Bay
Little
Bay
Channel
Port aux Basques
km
0
1
2
3
0
1
2
miles

Zone C:

garnet - kyanite - muscovite - biotite

kyanite - muscovite - biotite

garnet - muscovite - biotite +quartz and plagioclase (An. 20-30)

muscovite - biotite

Zone D:

garnet - sillimanite - muscovite - biotite

sillimanite - muscovite - biotite +quartz and plagioclase (An. 20-30) + potassium feldspar

garnet - muscovite - biotite

The boundary between zone A and zone B is defined by the incoming of kyanite and/or staurolite. The B - C boundary is defined by the disappearance of staurolite. The polymorphic transition between kyanite and sillimanite defines the C - D boundary. Garnet occurs in all four areas but is best developed in zone B. The occurrence of sillimanite decreases eastwards away from the C - D boundary. This reflects a compositional rather than temperature - pressure change since potassium feldspar is developed in the migmatite zone.

These zones, which describe curvilinear belts, are parallel to the D3 structures and show an increase in metamorphic grade from west to east with the progressive development of garnet, staurolite, kyanite, sillimanite and potassium feldspar. They are however a product of the D2 metamorphic event and their sharp boundaries, and apparent simplicity, is probably due to the masking effects of the later deformations.

The progressive grade is characteristic of the Barrovian metamorphic sequence (Barrow, 1893, 1912; Miyashiro, 1961). However

Table 3

Structural and Metamorphic History of the Port aux Basques Complex from the Cape Ray Fault to Isle aux Morts

Structure		Metamorphism	W → E				Intrusives
			W → E				W → E
		MP4	Chl. Musc. Bi.				
D4	Minor Crenulation	MS4	CHL. MUSC. BI.				
		MP3	Musc. Bi.	Musc. Bi. GT.	Musc. Bi. GT.	Musc. Bi. GT.	
D3	Tight Upright Folds of the Gneissic Banding	MS3	MUSC. BI.	MUSC. BI. GT. Ky	MUSC. BI. GT Sill	MUSC. BI. GT K.FELD	
		MP2	MUSC. Bi. GT.	MUSC. Bi. GT. ST. Ky	MUSC. Bi. GT. SILL.	MUSC. Bi. GT. KFeld	
D2	Isoclinal Recumbent folds closing to the northwest	MS2	MUSC. BI. GT.	MUSC. BI. GT. ST. KY.	MUSC. BI. GT. SILL	MUSC. BI. GT. KFELD	
D1		MP1	Bi. GT. ST.				Port aux Basques Granite
D1	Very poorly preserved	MS1	BI.				
Pre D1 History ?							

TIME ↑

CHL.=Chlorite; MUSC.=Muscovite; BI.=Biotite; GT.=Garnet;
ST.=Staurolite; KY.=Kyanite; SILL.=Sillimanite;
K.FELD.=Potassium feldspar;
MUSC.=Growth of the Mineral i.e. muscovite;
Musc.=Recrystallisation of the mineral i.e. muscovite.

the sequence here is spatially related to the Port aux Basques Granite in that there is an increase in grade towards the granite. The correlation between the granite and the high grade mineral assemblages is enhanced by the fact that the two are directly related in time.

The Port aux Basques Granite grades, to the southeast, into the migmatite zone, and no contact is found between the two. In the migmatite zone the granite bands show a relict gneissic banding (Plate 46) and the amphibolite pods show resorption effects at their margins.

It is therefore suggested that the migmatite zone forms the 'root zone' of the Port aux Basques Granite (c.f. Brown, 1967) and that the thermal event, associated with the development of the migmatites, and the intrusion of the granite, is to a great extent responsible for the development of the high grade mineral assemblages during MS2 and MP2.

Origin of the Gneissic Banding

A gneissose banding is ubiquitiously developed throughout the Port aux Basques Complex. Individual bands have distinct compositions and a compositional gradation between, and within, bands is rare. Intrafolial folds, contained within the banding, fold a small scale banding. This fine banding is compositionally similar to the transpositional banding developed in polyphasally deformed schists (Rast, 1966; Whitten, 1966).

This apparently simple, but in detail complex, type of banding is described from other gneiss complexes and its origin is generally attributed to either a process of metamorphic segregation (Sutton, 1972;

Kretz, 1960) or is regarded as a direct reflection of original sedimentary banding (Dietrich, 1960; Kalsbeek, 1965; Katz, 1970). Those authors who favour a sedimentary origin for the banding have, in general, obscured the problem, in that they have not differentiated between the origin of the rock and the origin of the banding in that rock, and have ignored the structural and metamorphic complexities which are inherent in gneissic banding.

There is also a tendency to take specific features of the gneissic banding and relate these to specific sedimentary features. If the two results are correlative then it is concluded that the gneissic banding is sedimentary in origin. This is particularly true of Katz (1970), who measured layer thickness in gneisses from Québec, Ceylon and Norway. It was found that the variations in layer thickness showed a log normal distribution and, since this type of distribution is also present in stratified sedimentary rocks, he concluded that the banding in the gneisses was sedimentary in origin. No mention is made of the structural complexities of the rocks (Wynne-Edwards, 1972; Appleyard, 1974), and since even a cursory consideration of the relative changes in bed thickness which accompanies isoclinal folding (Ramsay, 1965) indicates the improbability of relating the width of folded beds to undisturbed sediments, it is suggested that the conclusion is invalid.

Kretz (1960) from a mineralogical study of some Grenville gneisses concluded that the banding was a product of metamorphic segregation of felsic and mafic minerals during metamorphism. Sutton (1972) describes a gneissic banding which is very similar to, although apparently more complex, than that described from Port aux Basques.

He argues that the fine banding which is folded by intrafolial folds is compositionally similar to the transpositional banding developed in polyphasally deformed rocks (Rast, 1966; Whitten, 1966) i.e., metamorphic segregation has occurred, and that since the gneiss shows a complex structural history then the gneissic banding is essentially the result of mineral segregation during a complex series of repeated metamorphic and deformational episodes, some of the stages of which are indicated by the nature and orientation of the contained fabrics.

In the Port aux Basques Gneiss the presence of calc silicate bands, the abundance of pelitic to semi pelitic bands, and the overall lack of granitic bands, indicates that the gneiss was probably predominately sedimentary in origin. However, at least three major deformational and metamorphic episodes are recognised, and a fine composite banding is present throughout the gneiss i.e., metamorphic segregation has occurred, at least on a small scale. It is therefore suggested that although the gneiss was probably originally sedimentary in nature, the present gneissic banding is largely a product of metamorphic segregation during repeated metamorphic and deformational episodes, rather than a direct reflection of original sedimentary banding.

Reworked Zone

The description of the metamorphic history of the reworked zone will follow the pattern outlined in the description of the structural history and, wherever possible, the same sections will be used. This will enable the variations in structure and metamorphism to be correlated.

Shear Zones

The shear zones, although associated with the main part of the reworked zone are treated separately i.e., both the MS1 and MP1 growth stages are described in this section. The nucleation and growth of new mineral phases associated with the shear zones is variable both from the margins to the centre of each zone, and between zones. The western zones show a progression from breakdown of the gneisses at the margins to the nucleation and growth of muscovite, garnet and tourmaline and sillimanite towards the centre of the zones. The eastern zones show breakdown of the gneisses at their margins and the development of muscovite porphyroblasts towards the centre of the zones. Only one zone, which shows a complete gradation from breakdown at the margins to the development of sillimanite at the centre, is described.

MS1

At the margins of the zone the pre-existing gneissic fabrics are broken down with a finely comminuted mortar texture, and a fine mica-quartz intergrowth developed. Quartz, feldspar and mica show a decrease in grain size. Garnets are fractured and retrogressed to biotite and chlorite (Plate 47). The biotite is more iron rich than the gneissic biotite and shows a straw yellow to dark brown pleochroic scheme. Towards the centre of the zones the mortar texture becomes better developed and results in zones of comminution up to 3mm. across. Biotite and muscovite now occur as individual laths up to 2mm. in length. They are still however, distinctly smaller than the 'gneissic' micas. The 'gneissic' garnets are not retrogressed to the same extent as at the margins of the zone.

Farther towards the centre white mica porphyroblasts are developed. The growth of these porphyroblasts must have been exceedingly rapid since they both help define the S1 fabric and that fabric in part forms augen around them (Plate 48). They appear to be a regrowth of 'gneissic' micas rather than the nucleation and growth of a new phase. This is best seen where the original banding of the gneisses is folded (Plate 48). Within quartz-feldspar bands the original texture of the rock is now totally obliterated and quartz occurs as elongated grains with sutured boundaries. The elongation is in the plane of the new fabric. 'Gneissic' garnets are recrystallised and now show a dendritic habit along elongated quartz grain boundaries (Plate 49) indicating rapid growth (Voll, 1960). These garnets define a crude banding which is parallel to the gneissic banding, and attest their gneissic origin.

All of the shear zones show the above metamorphic 'steps' from the margin to the centre. The following 'steps' are however only present in the western zones. Sillimanite var. fibrolite is developed and occurs in elongated pods such that it helps define the new fabric, and in part, overgrows the porphyroblastic white mica (Plate 50). The 'gneissic' garnets show little tendency to be broken down although some crystals contain biotite 'inclusions' indicating possible incipient retrogression (Rast, 1965) (Plate 50). These biotite crystals are distinctly more iron rich than the 'gneissic' biotite.

Sillimanite var. fibrolite becomes better developed (Plate 51) and is accompanied by the nucleation and growth of garnet and tourmaline. The tourmaline occurs as acicular crystals which are present only where fibrolite is abundant and helps define the new fabric. However, fibrolite laths also form augen around the tourmaline and indicate rapid nucleation and growth of this mineral. The occurrence of garnet is totally different. This mineral has nucleated and grown throughout the entire rock regardless of composition (Plate 52). The crystals are all less than 1mm. in diameter, are subhedral to euhedral in outline, and do not contain inclusions.

MP1

There is no nucleation and growth of new mineral phases during the MP1 interval. Annealing recrystallisation has a very limited effect. At the margins of the zone the remnant 'gneissic' micas preserve their strained state and show undulose extinction. In the quartzo-feldspathic bands some recrystallisation has taken place and the grain boundaries are curvilinear rather than highly sutured.

Towards the centre of the zone most of the micas show straight extinction and the quartz-feldspar groundmass has recrystallised to a coarse equigranular texture. The grain boundaries, especially quartz-quartz, are however still quite highly sutured.

Sillimanite - white mica relationships

Sillimanite var. fibrolite is commonly associated with porphyroblastic white mica. Textural relationships could not resolve whether fibrolite is replacing white mica or vice versa.

The former view is suggested by:

(a) The optical continuity of the mica associated with fibrolite (Plate 53).

(b) White mica appears to have formed earlier than, although in part contemperaneous with, fibrolite.

The latter view is suggested from:

(a) White mica fills transverse fractures in the fibrolite (Plate 54).

(b) This mica is locally observed to be in optical continuity with mica crystals surrounding the fibrolite.

(c) Torpedo shaped lenses of white mica offshoot, parallel to the length of the fibrolite crystals, from the mica filled fractures (Plate 54).

This last observation implies a crystallographic control governing the replacement of fibrolite by white mica i.e., replacement occurs along rather than across the long axis of the fibrolite crystals. This control is a one way relationship i.e., the orientation of the mica does not control the replacement reaction.

The degree of alteration of the fibrolite also appears to be related to this crystallographic control. Where the fibrolite occurs as well orientated elongate pods, white mica occurs as a selvage around the edges of these pods, parallel to the long axis of the fibrolite, and as well developed crystals at the end of the pods, at right angles to the long axis of the fibrolite (Plate 55). Where muscovite occurs as large porphyroblasts which contain fibrolite, this fibrolite is usually observed to occur in rosettes i.e., the crystallographic control is minimised (Plate 56).

However, the validity of correlating the alteration of fibrolite along cross fractures, with the development of large porphyroblastic white mica crystals is questionable. It is therefore concluded that although fibrolite may replace white mica porphyroblasts, the reverse process also occurs, at least on a small scale.

Recumbent Folding

The metamorphism, like the structure, varies from west to east, with the higher grade assemblages occurring in the east. The descriptions will follow the sections outlined in the chapter dealing with the structure of the reworked zone. The main metamorphic event is associated with D1 (cover) and results in a breakdown and regrowth of the 'gneissic' minerals and the nucleation and growth of new mineral phases. The later events are usually retrogressive but locally progressive.

Section 1

MS1

The MS1 event is variable even over short distances. The poorly developed growth of muscovite and biotite define S1. The new biotite is distinctive in that it is strongly pleochroic i.e., straw yellow to dark brownish red. This type of biotite is also present in remnant 'gneissic' garnet porphyroblasts (Plate 57) and possibly indicates incipient retrogression of the garnet (Rast, 1965). Locally the 'gneissic' garnets are retrogressed to chlorite and sericite. Some of the crystals are completely altered to chlorite whilst others are only altered along cracks. They all however, retain their euhedral outline.

MP1

Partial recrystallisation of the quartz-feldspar groundmass results in curvilinear grain boundaries. Most quartz crystals are strained and show undulose extinction. The muscovite defining the S1 fabric locally forms porphyroblasts. These overgrow S1 and contain inclusions of quartz, feldspar and garnet.

Section 2

MS1

The 'gneissic' fabrics are tightly crenulated and the growth of muscovite and biotite define S1. Garnets are variably affected. In basic bands large porphyroblastic garnets show no evidence of retrogression (Plate 20). In leucocratic bands the garnets, especially the larger ones, have embayed rims and biotite is developed around these rims (Plate 58). This embayment destroys the regular outline of the garnets (Plate 58) and becomes more pronounced with increasing intensity of D1 (Plate 59). Quartz and feldspar, rather than biotite, fill the embayments, and a narrow biotite selvage is developed around the garnet rim. This selvage is poorly developed and locally absent where the embayment is most pronounced.

Tourmaline has nucleated upon 'gneissic' micas and at quartz-quartz and quartz-feldspar grain boundaries (Plage 60). The crystals are usually less than 2mm. in diameter and do not overgrow the S1 micas.

The MS1 metamorphism has reached, for garnet, a critical stage: The biotite selvages developed at the rims indicate a breakdown of the garnet. The embayments however, suggest a regrowth of garnet by grain boundary diffusion. This regrowth has taken place along quartz-quartz and quartz-feldspar grain boundaries, has a dendritic habit, and cross cuts the gneissic fabric (Plate 61).

Thus the garnets are being broken down to biotite i.e., retrogressed, and regrown, within the same rock. In the shear zones (described above) this regrowth is followed, towards the centre of the zones, by the abundant nucleation and growth of garnet and tourmaline. A new garnet phase is not observed here but the presence of abundant MS1 tourmaline may indicate that nucleation of this phase is close to occurring.

MP1

This event results in a variable recrystallisation of the quartz-feldspar groundmass. In pelitic bands quartz crystals are strained and the quartz-quartz and quartz-felspar grain boundaries are curvilinear. Micas are unstrained. In semi pelitic, pelitic and basic bands the grain boundaries are sutured and the micas show undulose extinction.

Section 3

MS1

The growth of muscovite and biotite define S1 and the 'gneissic' micas are now orientated parallel to S1. The regrowth of garnet is more pronounced here and most crystals now have a dendritic habit (Plate 62). Biotite selvages are not observed. Continued nucleation and growth of tourmaline occurs. Restricted nucleation and growth of a new garnet phase is observed in some highly schistose bands. These crystals are less than 0.1 mm. in diameter and occur at mica-mica grain boundaries

(Plate 63). It is not clear whether this growth is MS1 or MP1 due to the very small size of the crystals.

MP1

Recrystallisation of the quartz-feldspar groundmass results in curvilinear grain boundaries and an equigranular texture. Some of the MS1 micas form polygonal aggregates where they have overgrown an original mica rich band.

Section 4

MS1 - MP1

The overprinting effect of later deformational and metamorphic episodes now makes the distinction between MS1 and MP1 difficult to determine. The two will therefore be described together in this and the following sections. The D2 fabric forms augen around mica porphyroblasts, and garnet and tourmaline crystals. The mica porphyroblasts occur both as single crystals and as polygonal aggregates, which are flattened in the plane of S2. The garnets are generally less than 2mm. in diameter. The cores contain inclusions of quartz and feldspar which define straight trails. An inclusion free rim surrounds these cores. This may represent MS1 and MP1 growth respectively. However the fact that the trails are all straight indicates that the growth may be totally MP1 (Voll, 1960; Olesen, 1971). It is also possible that these garnets are remnant 'gneissic' garnets. Tourmaline is well developed and occurs as crystals up to 5mm. in length. These are orientated parallel to S2 and this fabric forms augen around them.

Section 5

MS1 - MP1

The composite S2 fabric forms augen around white mica porphyroblasts, and garnet and tourmaline crystals. The mica porphyroblasts occur as single crystals rather than polygonal aggregates although the latter form is still locally observed. Sillimanite var. fibrolite needles are present within these porphyroblasts. The garnets are similar to those described in the previous section but some crystals show three stages of growth i.e., an inclusion free core, surrounded by a 'murky' rim, which in turn, is surrounded by an inclusion free rim (Plate 64). This may be indicative of original (regrown?) gneissic garnets around which rapid MS1 growth has taken place, followed by slower MP1 growth to give an inclusion free rim. (Later observations, below, indicate that the latter two stages of growth may both be MP1). Tourmaline occurs as small subhedral crystals which locally contain quartz inclusions. No trails were observed.

Section 6

MS1 - MP1

The composite S2 fabric forms augen around white mica porphyrolasts, and garnet and tourmaline crystals. The mica porphyroblasts are smaller than those developed in section 5 and do not contain sillimanite. Tourmaline occurs as single crystals which locally contain quartz inclusions.

Two types of garnet are observed, atoll garnets (Williamson, 1935) and subhedral to euhedral garnets. The atoll garnets have embayed rims with quartz and feldspar filling the embayments. There is no biotite selvage around the rims but highly pleochroic biotite crystals occur as inclusions in some crystals. These garnets are similar to those found in the shear zones and section 2 (above), and are interpretated as remnant 'gneissic' garnets.

The subhedral to euhedral garnet crystals occur in association with the atoll garnets and are more numerous. They contain abundant inclusions of opaque minerals. These inclusions define various shapes, the most common being a six sided star (Plate 65). This is interpretated as representing rapid dendritic radial growth under 'static' conditions (Rast and Sturt, 1957; Rast, 1965). The intervening areas grow by layeritic growth (Rast, 1965). An inclusion free rim surrounds these areas of rapid growth. The layeritic growth has caught up with the dendritic growth prior to the growth of the inclusion free rim.

The growth features of these garnets are similar to that of the 'chiastolite cross' of andalusite, and are typical of static rather than dynamic growth (Rast, 1965). These garnets are attributed to an MP1 rather than an MS1 and MP1 growth phase.

It is pertinent to note here that the embayed atoll garnets described above are not found in the nearby Harbour le Cou Group. Subhedral to euhedral garnets showing dendritic radial growth patterns are however abundant. Within the cover sequence these garnets can be shown to be MP1 in age.

Slide Zones

MS1

Muscovite, biotite and slivers of opaque minerals define S1. The quartz-feldspar groundmass is finely comminuted and is flattened in the plane of this fabric. Where garnets are observed, S1 forms augen around them and they are severely embayed.

MP1

Very little MP1 recrystallisation has taken place and the quartz-feldspar groundmass still shows highly sutured grain boundaries. Muscovite and biotite have recrystallised to form strain free crystals.

D1 Growth of Garnet in the Reworked Zone

This section is concerned only with the growth of garnet in the recumbently folded part of the reworked zone from Granby Sound to Bay le Moine. At Granby Sound the garnets are 'gneissic' in origin and S1 forms augen around them. They are altered to chlorite and sericite but, even where this alteration is complete, the original euhedral outline of the garnet is still preserved. East of this biotite selvages are developed around the garnet rims. The rims are embayed, with quartz and feldspar filling the embayments. This destroys the original euhedral outline of the garnet and the crystals become skeletal. Where this is most pronounced the biotite selvages are absent.

Up to this point the garnets occur as porphyroblasts, are either retrogressed or regrown, and S1 forms augen around them. No nucleation of a new garnet phase is observed. These therefore represent relict 'gneissic' garnets and show, by their mode of breakdown, the progressive nature of the D1 metamorphic event.

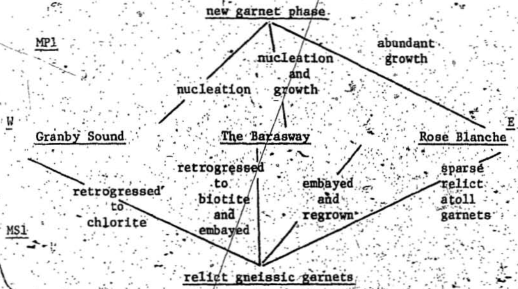
East of the Barasway the character of the garnets changes drastically. They are small euhedral to subhedral crystals, less than 3mm. in diameter, which have an inclusion rich core and an inclusion free rim. In the Rose Blanche to Bay le Moine area the inclusions define star shaped areas. Due to the small size of the garnets and the overprinting effects of the later deformational events it is not certain whether this growth is MS1 or MP1 or both. However, the star shaped inclusion filled areas imply MP1 growth (Rast, 1965) and a similar type of garnet growth, which is definitely MP1 in age, is observed in the nearby Harbour le Cou Group.

Thus in the reworked zone there is an MS1 breakdown and regrowth of remnant 'gneissic' garnets. With increasing grade of metamorphism, towards Rose Blanche, the relict garnets are no longer observed and a new MP1 garnet phase nucleated and grew. Locally in the Bay le Moine area relict atoll garnets are found.

There is thus a spatial and temporal relationship between the MS1 breakdown and regrowth of relict 'gneissic' garnets and the rapid nucleation and growth of an MP1 garnet phase (Fig. 6). It is therefore likely that the MP1 garnets are a re-nucleation and growth of the earlier 'gneissic' garnets.

Figure 6

D1 Growth of Garnet in the Reworked Gneiss



new garnet phase
MP1
nucleation
nucleation and growth
abundant growth
W
E
Granby Sound
The Barasway
Rose Blanche
retrogressed to chlorite
retrogressed to biotite and embayed
embayed and regrown
sparse relict atoll garnets
MS1
relict gneissic garnets

MS2

The growth of muscovite and biotite defines the S2 fabric. Although the MS1 and MP1 minerals are not retrogressed by this phase of metamorphism no new high grade minerals are developed. In the Rose Blanche area, where S2 is a composite fabric, the MS1 white mica porphyroblasts which contain fibrolite needles are broken down at the margins. The MS2 white mica crystals are orientated parallel to the S2 fabric and still preserve the fibrolite needles.

The quartz-feldspar groundmass has recrystallised and the grain boundaries are sutured to curvilinear. In the slide zones the earlier fabric is largely transposed and the quartz-feldspar groundmass is still highly strained.

MP2

The MP2 event is restricted to minor recrystallisation. The micas defining S2 are strain free but no porphyroblastic white mica growth is observed. The quartz-feldspar groundmass has partially recrystallised and polygonised and many of the grain boundaries are curvilinear.

MS3

This is a retrogressive phase of metamorphism with the S1 and S2 micas being altered to chlorite and sericite. At F3 fold hinges the pre-existing micas are broken rather than folded around the cores (Plate 66). The growth of biotite locally defines S3. In the quartz-feldspar rich bands S3 is defined by a mortar texture.

MP3

A minor phase of metamorphism within which little recrystallisation and polygonisation has occurred. The micas which were folded and broken during D3 still show undulose extinction and the quartz and feldspar grain boundaries are sutured.

Calc Silicate Bands

Calc silicate bands occur as discontinuous pods and lenses close to the Rose Blanche Granite within the reworked gneiss, and have acted as competent units which have been boudinaged during the reworking deformations. They are anomalous in that their mineralogy is indicative of high temperature-low pressure metamorphism whilst the surrounding gneisses only show regional metamorphic effects.

The mineral assemblages are: grossular - diopside - zoisite - plagioclase - quartz - calcite - sphene and apatite. grossular - wollastonite - vesuvianite - calcite - quartz - xonotlite and apatite.

Grossular shows cyclic growth with zoisite, calcite and vesuvianite (Plate 67). Wollastonite occurs as unorientated fibrous aggregates in fine bands which parallel the contact between the calc silicate band and the granite.

The mineral assemblages, the unorientated nature of the intergrowths, and the proximity of the bands to the Rose Blanche granite, indicate that the bands have been hornfelsed by the granite.

The upper boundary of the hornblende hornfels facies of metamorphism is, in part, defined by the reaction

calcite + quartz $\rightleftharpoons$ wollastonite + CO_2 (Reverdatto, 1973)

The presence of grossular implies hornblende hornfels metamorphism (Reverdatto, 1973). However, the occurrence of vesuvianite implies pyroxene hornfels (Turner, 1968). It is therefore proposed that the grade of metamorphism was close to the hornblende-pyroxene hornfels boundary.

Subsequent to the formation of the above mineral assemblages the calc-silicate bands were deformed and subjected to regional metamorphism. Diopside is altered, locally completely, to hornblende. This hornblende is orientated parallel to the D1 (cover) fabric. Wollastonite is extensively retrogressed to calcite and plagioclase to epidote and sericite. Xonotlite is retrogressed to a carbonate. Grossular shows no retrogressive effects. Locally a fine banding, consisting of a fine granular aggregate of quartz, feldspar, hornblende and epidote is developed at the margins of the bands. The banding parallels the D1 structures outwith the calc silicates and is attributed to that deformation.

The Rose Blanche Granite is observed to hornfels the Port aux Basques Gneisses in the Isle aux Morts to Granby Sound area. However, east of this the contact metamorphic effects are totally obliterated in all but the calc-silicate bands due to the overprinting by the regional deformational and metamorphic events. The preservation of the contact metamorphic assemblages within the calc silicate bands is attributable to the competent behaviour of these bands during the reworking deformations i.e., they formed boudinage structures around which the gneisses were reconstituted.

Table 4

Structural and Metamorphic History of the Reworked Gneiss from Isle aux Morts to Rose Blanche

TIME	Structure			Metamorphism				Intrusives
	W → E			W → E				W → E
↑				MP3			Chl. Musc. Bi.	
	D3		Kinks and open folds	MS3			CHL. MUSC. BI.	
				MP2			Musc. Bi. Sill.	
	D2		Tight folds overturned to the southeast	MS2			MUSC. BI. Sill.	
				MP1	Chl. Bi. MUSC. Sill.	Chl. Bi. MUSC. GT.	MUSC. Bi. GT. Sill.	
	D1	Shear Zones	Recumbent folds overturned to the southeast and tectonic slides	MS1	CHL. BI. MUSC. GT-Gt. TOUR. SILL.	CHL. MUSC. BI. Gt. TOUR.	MUSC. BI. GT. TOUR. SILL.	
	Hornfels texture preserved only in the Calc. Silicate bands							Rose Blanche Granite

Table 4 (continued)

CHL. = Chlorite; MUSC. = Muscovite; BI. = Biotite; GT. = Garnet;
TOUR. = Tourmaline SILL. = Sillimanite;
GT. = Growth of Garnet; Gt. = Recrystallisation of Pre-existing garnet.

Harbour le Cou Group

The description of the metamorphic history of the Harbour le Cou Group will follow the pattern outlined in the description of the structural history. Wherever possible the same sections will be used as those for the structural history.

MS1

In the west MS1 growth is restricted to muscovite and biotite. Biotite predominates and occurs in discreet bands. These bands are irregular and reflect original compositional variations which are attributed to sedimentary processes. In the central and eastern part of the section muscovite becomes the dominant mica and, close to the Harbour le Cou Slide, occurs as large porphyroblasts. The growth of acicular sillimanite var. fibrolite is associated with the Harbour le Cou Slide.

The quartz-feldspar groundmass recrystallised during MS1, and the sedimentary features of the rock i.e., graded bedding, obscured.

MP1

This is the main phase of progressive metamorphism in the Harbour le Cou Group and garnets are developed over the entire area. Locally, close to the Harbour le Cou Slide, fibrolite occurs in association with biotite (Plate 68). In the western part of the section the garnets are less than 3mm. in diameter although those occurring in biotite rich bands tend to be larger than those occurring in quartz rich-biotite poor bands. In outline they are subhedral to euhedral, the former predominating. They overgrow S1 and locally contain inclusions of quartz and feldspar which define straight trails. These inclusions are restricted to the central part of the crystals and are surrounded by an inclusion free rim. In some garnets fine opaque inclusions define star shapes (Plate 69). These are restricted to the central part of the crystals and are surrounded by an inclusion free rim. They are similar in appearance to the chiastolite cross of andalusite and represent rapid radial growth (Rast, 1965). Locally plagioclase (Albite ?) porphyroblasts, twinned on the Carlsbad law, are developed. One crystal contains inclusions which define trails which are concordant with S1.

In the central part of the section the garnets tend to be larger and better developed, especially in the biotite rich bands. In this area the exact relationship of the garnet growth with respect to S1 is uncertain due to the overprinting effects of the later deformational events. The crystals are however pre D2 since S2 forms augen around them. The central portion of the crystals, which contain inclusions, is generally much smaller than that observed in the west, but the inclusion free rim is much better developed. Straight inclusion trails, defined by quartz and feldspar, were noted (Plate 70) and imply MP1 rather than MS1 growth (Zwart, 1960). No star shaped growth was observed.

In the east the first fabric is almost totally transposed by D2 and S2 forms augen around subhedral garnet crystals. These garnets generally contain fine opaque inclusions which define a variety of shapes including six pointed and four pointed stars and double ended Ys (Plate 71). The amount of included material is highly variable.

Where it is sparse the shapes are well defined. Usually however the entire central part of the crystal is filled with opaques and no definite shape is obvious. The inclusion rich cores are always surrounded by an inclusion free rim (Plate 71).

Several crystals show a more complex growth history i.e., subhedral inclusion poor central area surrounded by an inclusion rich area. This, in turn is surrounded by an inclusion free rim.

These features (above) allow a garnet growth history to be delineated. The scarcity of garnets showing inclusion free central portions implies initial restricted nucleation and slow growth. (These may be MS1 in age). This is followed by rapid nucleation and dendritic growth accompanied by slower layeritic growth between the dendrites. The layeritic growth appears to have caught up with the dendritic growth prior to the final growth phase which is the slow accumulation of an inclusion free rim.

The large MS1 muscovite porphyroblasts developed close to the Harbour le Cou Slide are recrystallised and inclusion free garnets are included within the MP1 crystals. The regrowth is however mimetic and the D1 fabric is preserved.

MS2

The MS2 event is restricted to the growth of muscovite and biotite and the recrystallisation of the quartz-feldspar groundmass. The micas overgrow the earlier fabric and on the fold limbs the two fabrics are subparallel. In the central and eastern part of the section muscovite is the dominant mica and a composite style of fabric is developed.

Table 5

Structural and Metamorphic History of the Harbour le Cou Group from North of the Barasway to Bay le Moine

W ⟶ E W ⟶ E W ⟶ E

Structure		Metamorphism		Intrusives
		MP3	Chl	
D3	Kink bands and open folds	MS3	CHL	
		MP2	Bi Musc.	
D2	Tight upright folds overturned to the southeast	MS2	BI MUSC.	
		MP1	Bi MUSC. GT Sill	
D1	Recumbent folds overturned to the southeast and tectonic slides	MS1	MUSC. BI TOUR SILL	
				Rose Blanche Granite

TIME ⟶

CHL. - chlorite, BI. - biotite, MUSC. - muscovite, GT. - garnet

TOUR. - tourmaline, SILL. - sillimanite

SILL = Growth of the mineral

Sill = Recrystallisation of that mineral

The quartz-feldspar groundmass recrystallises during MS2 and the original sedimentary features of the rock are partially obliterated in the west and totally obliterated in the east.

MP2

Unlike MP1 no high grade minerals are developed during MP2 and this event is restricted to the recrystallisation of the quartz-feldspar groundmass.

MS3

In the west this is a retrogressive phase of metamorphism and biotite is altered to chlorite and muscovite partially altered to sericite. In the east muscovite and biotite are tightly folded and the crystals fractured and broken. No retrogression has however taken place.

MP3

The effects of this phase of metamorphism are only present in the eastern part of the section where the mica crystals which are bent and broken by the third deformation are polygonised and strain free.

Bay du Nord Group

The Bay du Nord Group has been subjected to both thermal and regional metamorphic events. The thermal metamorphism is related to the intrusion of the Petites Granite and the La Poile Batholith. Both granites were intruded into the Group after the first but before the second phase of deformation. The regional metamorphism is related to the regional deformational events.

Thermal Metamorphism

Petites Granite

Due to later regional metamorphic overprinting, the contact aureole fo the Petites Granite is only preserved in the sediments close to the contact. The mineral assemblages attributable to hornfelsing fall within the hornblende hornfels facies, as defined by Turner (Turner, 1968 p. 193).

Pelitic:

muscovite - biotite - cordierite

muscovite - biotite - andalusite

Psammitic:

biotite - garnet

Calcareous:

actinolite - garnet

The cordierite porphyroblasts occur in bands which conform to the bedding and are generally completely altered to pinite by the later regional metamorphic events. Where preserved they show well developed lamellar twinning and have a strong yellow to colourless pleochroism (Plate 72).

Andalusite, like cordierite, tends to occur in bands which parallel the bedding. Within these bands the crystals show no preferred orientation. The porphyroblasts are well developed, contain inclusions which define straight trails, and are altered at the rims to a fine sericitic material, by the later regional metamorphic events (Plate 73). Porphyroblasts, found well away from the granite contact, at Garia Bay, are composed entirely of sericite and quartz and the main fabric forms augen around them (Plate 74). It is suggested that these are andalusite crystals which have been totally retrogressed during D2.

Actinolite occurs as randomly orientated laths up to 1mm. in length within fine calcareous beds. The crystals show green to colourless pleochroism and have an extinction angle of 10°, indicating a composition close to ferroactinolite in the tremolite-ferroactinolite series. Inclusions of garnet and an opaque mineral (magnetite ?) are quite common.

Garnets occur in a predominantly ~~psammitic~~ sequence with interbedded calcareous beds. They are usually less than 2mm. and show a turbid core and a clear rim. The turbid cores have a well rounded outline, whilst the clear rims define a subhedral outline (Plate 75). Where they are abundant the garnets occur in layers which parallel the bedding and locally define the base of the beds. Where the garnets occur with actinolite in the calcareous beds the actinolite is observed to overgrow and include the garnets. These crystals do not have a clear rim (Plate 76). Adjacent pelitic bands do not contain garnets.

These features indicate that the turbid cores of the garnets represent sedimentary grains, that they were deposited in layers presumably due to heavy mineral separation, and that subsequent metamorphism resulted in an overgrowth around the detrital grains. Where these garnets are observed, the regional metamorphic events are poorly developed and the thermal metamorphic effects well preserved i.e., actinolite, andalusite. The growth of the clear garnet rim is therefore attributed to the thermal metamorphic event.

La Poile Batholith

The hornfels associated with the La Poile Batholith is poorly developed and poorly preserved. Biotite appears to have been the main mineral developed during the thermal event. Sericite pods are observed close to the contact. These are similar to the retrogressed andalusite porphyroblasts associated with the Petites granite. However no remnant crystals were found. The later regional events almost totally overprint the hornfels.

Regional Metamorphism

The regional metamorphic events are related to the three deformations recognised in the Bay du Nord Group. Of these, the metamorphic growth phase associated with the first deformational event is best developed and shows a variation from biotite grade in the east to garnet grade in the west. The second and third events are of much lower grade.

MS1

Mineral growth attributable to MS1 is recognised between the S2 schistosity planes and as inclusion trails in garnet and andulusite porphyroblasts. In the east biotite is well developed in the psammitic beds and occurs as individual laths up to 0.5mm. in length. In pelitic bands the fabric is defined by fine felted laths of white mica. Westwards towards Bay le Moine biotite is the dominant mica and is quite coarsely developed.

MP1

In the east the MP1 event is restricted to the continued growth of the micas. At Bay le Moine garnets are developed. There are at least two stages of growth, an early rapid growth containing inclusions, and a later slower inclusion free growth (Plate 77). The S2 fabric forms augen around these crystals, and where S1 is observed they appear to overgrow that fabric. The inclusions locally define straight trails. No curved trails were observed. Although the inclusion free rim is MP1 in age the relationship of the inclusion filled core to S1 could not be determined. However, the lack of curved, and the presence of straight inclusion trails implies MP1 rather than MS1 growth (Voll, 1960; Olesen, 1971). These crystals do not show the star shaped inclusion filled areas that are characteristic of early MP1 growth in the Harbour le Cou Group.

MS2

The growth of muscovite and biotite define the S2 fabric. In the eastern part of the area biotite is well developed in the psammitic bands. In pelitic bands muscovite is the dominant mica. This fabric forms augen around the andalusite and cordierite porphyroblasts related to the thermal event. Most of these crystals are at least partially altered to white mica during S2. In the Bay le Moine area the fabric forms augen around the MP1 garnets.

MP2

The MP2 event is generally restricted to the partial polygonisation of the quartz-feldspar groundmass and the MS2 micas. However, close to the Petites Granite, between Bay le Moine and Little Garia Bay, MP2 cordierite is developed in the sediments. The crystals form along distinct bands and show well developed six fold sector twinning. They overgrow and include the D2 fabric (Plate 78). This cordierite only occurs in close association with the post D1 pre D2 thermal cordierite related to the Petites Granite. These latter crystals are retrogressed to pinite during MS2.

Two possible origins are considered for this MP2 cordierite, either a second thermal event or a static growth phase related to the D2 deformation. A second thermal event is thought to be unlikely since the S2 fabric is well preserved and the granite shows no evidence of being a multiphase intrusive.

However, if it is a static growth phase related to a regional event then its occurrence should not be restricted to close to the granite contact, which it is. It is proposed that the MP2 cordierite is not related to the Petites granite but is related to the post D1 pre D2 cordierite which grew as a result of thermal metamorphism by that granite, in that these crystals, or the remnants of them, could have acted as nuclei upon which the MP2 growth preferentially took place.

MS3

This event is retrogressive rather than progressive. In the east MP2 micas are bent and polygonised and partially reorientated to define S3. In the west minimal reorientation has taken place and biotite and garnet are partially retrogressed to chlorite.

Table 6

Structural and Metamorphic History of the Bay du Nord Group from Bay le Moine to Garia Bay

W → E   W → E   W → E

TIME ↑

Structure		Metamorphism				Intrusives		
		MP3	Chl. Musc. Bi.					
D3	Crenulation Cleavage	MS3	CHL. Musc. BI.					
		MP3	Musc. Bi. CORD					
D2	Tight upright folds	MS3	Musc. BI. Cord.					
		BI ACT CORD AND GT			BI	PETITES GRANITE		LA POILE BATHOLITH
		MP1	Musc Bi GT	Musc. Bi				
D1	Large scale recumbent folds	MS1	MUSC BI	MUSC BI				

CHL. - chlorite, BI. - biotite, MUSC. - muscovite, GT. - garnet, CORD - Cordierite, ACT. - Actinolite AND. - Andalusite

BI = Growth of the mineral i.e., Biotite
Bi - Recrystallisation of the mineral i.e., Biotite

MP3

This is a very minor phase with little recrystallisation and polygonisation. The micas which are broken during D3 still show undulose extinction and the quartz and feldspar boundaries are sutured.

Windsor Point Group

The metamorphism of the Windsor Point Group is restricted to the Greenschist Facies.

MS1

The S1 fabric is defined by the growth of muscovite, actinolite and epidote. The muscovite is best developed in the shales, arkoses and rhyolites and occurs as crystals up to 1mm. in length (Plate 79). Actinolite and muscovite define S1 in the tuffaceous units. Epidote is best developed in basic pebbles in the conglomerate.

MP1

This is a minor phase of metamorphism. The micas are still strained and the quartz-feldspar groundmass shows little evidence of recrystallisation.

MS2

Close to the Cape Ray fault muscovite growth defines S2. On the fold limbs S2 has a strain slip relationship to S1 (Plate 79). At the fold cores the S1 micas are bent and broken and S2 is poorly developed. Chlorite is developed in the tuffaceous bands.

Table 7

Structural and Metamorphic History of the Windsor Point Group from Osmond Point to the Cape Ray Fault

W → E   W → E   W → E

	Structure	Metamorphism		Intrusives
		MP3	Musc.	
D3	Kink band formation	MS3	MUSC	
		MP2	Musc. Chl	
D2	Tight upright folds	MS2	MUSC CHL	
		MP1	BI Musc.	
D1	Upright folds tightening eastwards towards the Cape Ray fault	MS1	BI MUSC EP ACT	

TIME →

CHL. – chlorite, MUSC. – muscovite, EP. – Epidote

ACT. – actinolite, BI. – biotite

CHL – Growth of chlorite

Chl – recrystallisation of chlorite

MP2

The SI micas still show undulose extinction. The quartz-feldspar groundmass of the rock shows highly sutured grain boundaries.

MS3

S1 and S2 micas are broken along kink planes.

MP3

The broken micas are still strained and quartz-quartz boundaries are highly sutured.

Cape Ray Fault Zone

The metamorphism related to the formation of the Cape Ray Fault Zone is totally retrogressive. The development of the mylonite banding resulted in the breakdown of the gneissic fabrics in the Port aux Basques and Cape Ray Complexes, and the segregation of felsic and mafic elements to define the banding. The felsic bands are comprised of quartz and potassium feldspar. Epidote, biotite and chlorite define the mafic bands.

The metamorphism related to the later three periods of deformation is restricted to a recrystallisation and reorientation of the minerals defining the mylonitic banding.

MS1

The growth of biotite and chlorite and reorientation of the existing biotite and chlorite define the S1 schistosity. Migration of quartz and feldspar at the ~~F1~~ fold hinges locally results in a transposition of the banding.

MP1

This phase is restricted to a recrystallisation of the quartz-feldspar bands resulting in a polygonal aggregate. The straight grain boundaries are controlled by the (001) plane of biotite (Kretz, 1966; Vernon, 1968).

MS2

A reorientation and growth of biotite and chlorite define the S2 schistosity. The earlier banding is little disrupted by this phase (Plate 35).

MP2

A minor phase in which little recrystallisation has taken place since most of the quartz and feldspar crystals show undulose extinction and are still highly strained.

MS3

Biotite and chlorite crystals are bent and broken at fold hinges and along kink planes. No S3 schistosity is developed.

MP3

This phase is only very locally significant with slight recrystallisation along kink planes. The bent crystals however still show undulose extinction.

Table 8

Structural and Metamorphic History of the Cape Ray Fault Zone

TIME

Structure		Metamorphism		Intrusives
		MP3	Chl	
D3	Kink bands	MS3	Chl	
		MP2	Chl Bi	
D2	Open to tight folds of the mylonite banding	MS2	CHL BI	
		MP1	Chl Bi	
D1	Isoclinal folding of the mylonite banding	MS1	CHL BI	
FORMATION OF THE MYLONITE BANDING				

BI - Biotite, CHL - chlorite

BI = Growth of Biotite

Bi = Recrystallisation of Biotite

CHAPTER 8

BASEMENT-COVER RELATIONSHIPS

Nature of the Reworking

Examples of deformed basement-cover contact zones are taken from the Nagssugtoqidian Mobile Belt in Greenland (Bridgewater *et al.*, 1973), the Limpopo Mobile Belt in Africa (Mason, 1973; Coward *et al.*, 1973), and the Laxford Front in northwest Scotland (Sutton and Watson, 1951; Beach *et al.*, 1974). These deformed contacts are typically zones of intense deformation within which a structural pattern, dominated by planar elements, is developed, and inherited features are difficult to recognise. They are characterised by parallel alignment of lithological boundaries, schistosities and intrusives. (Watson, 1973).

A change in tectonic style is commonly observed, across these zones, with shear zones, or 'straight belts' (Hepworth, 1967) being developed in the basement rocks, followed laterally and/or upwards, towards cover rocks, by recumbent folds which infold the cover rocks into basement rocks. (Beach *et al.*, 1974; Mason, 1973; Bridgewater *et al.*, 1973; Coward *et al.*, 1973).

Where a structural sequence has been determined, the earliest deformation to affect the basement-cover contact appears to be the most penetrative (Beach *et al.*, 1974) and the reconstitution of the basement largely related to this event. The development of shear zones and recumbent folds is also related to this deformation. Later phases result in upright structures which, although further obscuring the basement-cover contact relationships, do not cause a farther widespread reconstitution of the basement.

Although on a much smaller scale, the basement-cover relationships in the study area conform to the overall pattern shown by the above examples. The actual contact zone, is, however, exceedingly difficult to recognise since the progressive (west to east) reconstitution of the gneisses results in a fine grained semipelitic rock which is indistinguishable, lithologically, from the cover rocks. There is thus, in the study area, an apparent complete gradation from basement rocks in the west to little deformed cover rocks in the east. This gradation is due to a structural and metamorphic convergence across the basement-cover contact zone.

At Isle aux Morts the Port aux Basques gneisses are cut by narrow, sharply bounded shear zones which dip steeply to the northwest. Within these zones the banding is transposed and a new fabric developed. Accompanying the development of this fabric muscovite porphyroblasts, biotite, garnet, tourmaline and sillimanite var. fibrolite have nucleated and grown. The new growth only occurs towards the centre of the zones. At the margins the gneissic minerals are retrogressed.

Eastwards towards Granby Sound the shear zones, although still occuring as discreet units, begin to have a regional rather than local effect i.e., the associated fabric is developed throughout the gneisses. This change in style of deformation is accompanied by a shallowing of the northwest dip of the zones and an overall decrease in the grade of metamorphism. Within the zones muscovite porphyroblasts and biotite are well developed. Outside the zones the 'gneissic' mineralogy is retrogressed, usually to chlorite.

At Granby Sound the new fabric is developed throughout the gneiss and is axial planar to recumbent folds which are overturned to the southeast. The development of this fabric results in a crenulation of the gneissic fabrics. The associated metamorphism is retrogressive with biotite and garnet being altered to chlorite. Garnetiferous leucocratic granite dykes are abundant here. They cross cut the gneissic banding, contain the new fabric, and are either folded or boudinaged, depending upon their orientation, by this deformational event.

East of Granby Sound the recumbent folds locally become upright. The axial planar fabric is well developed and is defined by the growth of muscovite and biotite laths, and the earlier gneissic fabrics are locally transposed parallel to this fabric, especially at fold cores. On the fold limbs the two fabrics are subparallel. The grade of metamorphism has increased and chlorite is no longer developed. 'Gneissic' garnets are retrogressed to biotite, become embayed, and their original euhedral outline destroyed. Tourmaline, as well as muscovite and biotite has nucleated and grown as a new mineral phase.

The new mineral growth is on a much finer scale than the mineral growth associated with the development of the gneisses. There is thus an overall tendency towards a reduction in grain size with progressive reworking. The gneissic banding is however still apparent here and is cross cut by garnetiferous leucocratic granite dykes. These dykes contain the new fabric, and are either folded or boudinaged by this event.

At White Head the gneisses are folded into a tight recumbent synform, with the axial planar fabric being the dominant fabric in the rock. This synform can be traced northeast along strike and becomes a zone of intense deformation, across which no change in vergence, between the new fabric and the gneissic banding was observed. The synform is thus pinched out and a tectonic slide developed along its trace. Basic bands which, in the Port aux Basques area formed part of the gneissic banding, now occur as small pods and lenses around which the axial planar fabric forms augen. Muscovite, biotite, tourmaline, and garnet have nucleated and grown as new mineral phases. With increasing development of the new growth phases the reduction in grain size becomes more pronounced. Large relict 'gneissic' garnets are not found here.

At the Barasway the new fabric is the main fabric in the gneisses and the earlier gneissic fabrics are transposed parallel to it. This transposition results in a finely foliated quartzo-feldspathic rock. Remnants of the original gneissic banding are found as lenses within the finely reconstituted rock. Abundant nucleation and growth of garnet and tourmaline is associated with the deformation here. Garnetiferous leucocratic granite dykes rarely show cross cutting relationships and are usually intensely flattened and boudinaged within the plane of the new fabric. The large garnetiferous granite sheets are also conformable with the new fabric.

Between the Barasway and Bay le Moine the gneisses are almost totally reconstituted to a finely schistose quartzo-feldspathic rock. Gneissic remnants are rare but, where observed, occur as pods and lenses around which the new fabric forms augen. Sillimanite var. fibrolite, muscovite porphyroblasts, garnet and tourmaline, as well as muscovite and biotite laths, are well developed here. Apart from the local development of sillimanite and muscovite porphyroblasts the reconstituted gneiss is characterised by a fine equigranular texture with mineral orientation defined by fine laths of muscovite and biotite. Although the reconstitution is most advanced here estimates of the amount of deformation (R value of Watterson, 1968) could not be determined due to the lack of objects of known predeformational shape. Also, the deformation is inhomogeneous in that tectonic slides are developed. Recognition of the cross cutting relationships of the garnetiferous leucocratic dykes is exceedingly difficult since most are orientated parallel to the new fabric and isoclinally folded.

East of Bay le Moine the gneisses once more become recognisable as such. In the Garia Bay area the new fabric, defined by muscovite and biotite laths is well developed and garnetiferous leucocratic granite dykes are isoclinally folded by this deformation. The original banded nature of the gneiss is still apparent, and little reconstitution has occurred.

The cover sequence, the Harbour le Cou Group, occurs as two slivers which are infolded into gneisses during this deformational episode. The new fabric (above) is the first tectonite fabric observed in these rocks. North of the Barasway possible relict sedimentary features are observed. The deformation increases in intensity eastwards and, in the Harbour le Cou area, all evidence of sedimentary structures are totally obliterated. The grade of metamorphism also increases eastwards with the development of sillimanite close to the Harbour le Cou Slide at Harbour le Cou. Garnets, which are better developed in the east than the west, are also related to this event. They show limited syntectonic, but abundant post-tectonic nucleation and growth. This static growth results in crystals with star-shaped inclusion rich areas surrounded by inclusion free rims.

Within the cover sequence the garnetiferous leucocratic granite dykes are never observed to cross cut a fabric which is earlier than the fabric which they themselves contain.

The contact relationships between basement and cover rocks can be delineated where it is a tectonic slide. Where the contact is apparently not a slide it could not be accurately determined. The northern sliver of the Harbour le Cou Group is bounded, to the north, in the Harbour le Cou area by a tectonic slide. Although the cover sequence can be traced to north of the Barasway the slide can not be traced for any great distance west of Harbour le Cou. Between these two localities the northern contact between basement and cover could not be determined. The southern boundary of the northern sliver is a tectonic slide, the Harbour le Cou slide. At the Barasway, basement rocks to the south of the slide contain abundant relicts of gneissic banding. Those to the north contain relicts of what are thought to be sedimentary structures. Garnetiferous leucocratic granite dykes cross cut early tectonic fabrics in the rocks to the south of the slide. This relationship is not observed to the north of the slide.

The southern sliver is bounded, on the west side of Harbour le Cou Bay, by tectonic slides. These are poorly exposed in the Rose Blanche area and the actual contacts are extremely difficult to determine. Approximate boundaries are deduced from the cross cutting relationships of the garnetiferous leucocratic granite dykes. The western extent of this sliver is defined by what is thought to be a conglomerate.

A second cover sequence, the Bay du Nord Group, occurs to the east of the Harbour le Cou Group, but can not be directly related to this Group since the two are separated by the Bay le Moine Fault. However, the structural and metamorphic sequences in both groups are similar and, in part, conformable. Therefore although the groups may be of different stratigraphic age they have been subjected to the same deformational and metamorphic episodes. The earliest fabric (above) is well developed and defined by the growth of muscovite and biotite laths. The associated folds are large scale and recumbent. The metamorphic grade decreases from west to east with garnets developed only at Bay le Moine. These garnets, although not containing the star shaped inclusion rich areas which are so characteristic of the garnets developed in the Harbour le Cou area, do have inclusion rich cores. These inclusions define straight trails indicating post tectonic rather than syntectonic growth.

The basement - cover contact has been further deformed. This deformation is not as penetrative as the earlier phase and is only developed east of the Barasway. It is however, most intense close to the basement - cover contact at Rose Blanche and further obscures that contact. A penetrative fabric, defined by muscovite and biotite laths is always well developed. In the Rose Blanche - Harbour le Cou area this phase transposes the earlier fabrics, both in the basement and cover rocks. The deformation is however inhomogeneous, and zones of total transposition are separated by zones of isoclinal folding within which the earlier fabrics are easily recognisable. Within the Harbour le Cou

Group this fabric is the dominant fabric in the rock. The associated metamorphism is of much lower grade than that related to the earlier episode. Muscovite and biotite laths are well developed but no garnet or sillimanite nucleation and growth occurs. Garnetiferous leucocratic granite dykes are isoclinally folded by this deformation.

To the east, in Garia Bay, the gneisses are tightly folded by this event. No transposition of the earlier fabrics is however observed. The growth of muscovite and biotite laths defines the fabric. No high grade mineral growth was noted.

This phase of deformation results in tight upright folds in the Bay du Nord Group. The axial planar fabric, defined by muscovite and biotite laths, is conformable with the second fabric in the Harbour le Cou Group and reworked gneiss. The grade of metamorphism is restricted to the development of muscovite and biotite.

The final event to affect the basement-cover contact is an open warping of the previous structures about a north-south axis. This deformation is not as penetrative as the previous phases. An upright crenulation cleavage is locally developed. The only large scale structure associated with this phase is an open antiform in the Harbour le Cou - Bay le Moine area. The associated metamorphism is retrogressive, with the development of chlorite.

In the Bay du Nord Group an upright north-south trending crenulation cleavage is locally well developed. This is associated with an antiformal structure to the east of the study area. The metamorphism is retrogressive with sericite and chlorite being developed.

The basement-cover relationships are therefore characterised by (a) a changing style of deformation from the basement to the cover with the development of shear zones, recumbent folds and tectonic slides, (b) an increase in intensity of deformation towards the basement-cover contact from both the basement and the cover, and (c) an increase in grade of metamorphism towards the basement-cover contact from both the basement and the cover.

These features, especially the latter two, result in a complete reconstitution of the gneiss close to the basement-cover contact such that the gneiss becomes, lithologically, indistinguishable from the cover rocks.

Later deformations, although not as penetrative as the early phase, partially transpose the earlier fabrics close to the basement-cover contact zone. This further obscures the contact.

Age of the Reworking

The deformations resulting in the reworking of the Port aux Basques Complex and the infolding of the younger cover rocks obviously postdates the formation of the Port aux Basques Complex since these phases overprint the gneissic fabrics. The age of the Port aux Basques Complex is unknown. The cover rocks can however be dated, by correlation, as Lower Devonian in age. This implies that the reworking deformations are, at the oldest, an Acadian event. This conclusion is based on two correlations (a) the equivalence of the Bay du Nord Group in Garia Bay to the Bay du Nord Group, as described by Cooper (1954) north of La Poile, and (b) the equivalence of the structures in the Harbour le Cou Group with those in the Bay du Nord Group at Garia Bay.

The Bay du Nord Group at Garia Bay is a pro-delta sequence consisting essentially of black slates with subordinate fine sands and local grit, conglomerate, and calcareous beds. The present strike of these beds is northeast i.e., directly towards the Bay du Nord Group north of La Poile. The Bay du Nord Group north of La Poile consists essentially of black slates with subordinate argillaceous quartzite and greywacke and minor conglomerate and limestone beds, deposited in a deltaic environment. (Cooper, 1954). Fossil plants, found in the slates give a Lower to Lower Middle Devonian age for the Group. Both Groups have been deformed, but the deformational episodes can not be correlated since Cooper did not outline a structural sequence. The metamorphism of both is predominantly low grade. However, northeast, along strike from the fossil localities, Cooper records a gradational metamorphism between the slates and gneissic rocks. This gradation is marked by the development of garnet and hornblende accompanied by the coarsening of biotite growth. This is similar to the development of garnetiferous schists in Bay le Moine.

Williams (1967) directly correlated the sequences in Garia and Little Garia Bay with the Devonian rocks north of La Poile. Gillis (1972) also correlated the two sequences but separated them by a sequence of 'slates, quartzites, tuffs, conglomerates, and metamorphic equivalents', which he ascribed to the Port aux Basques Complex. Therefore, the Bay du Nord Group at Garia and Little Garia Bay is here correlated with the Bay du Nord Group north of La Poile and is hence Lower to Lower Middle Devonian in age.

The Harbour le Cou Group is separated by the Bay le Moine Fault, from the Bay du Nord Group at Garia and Little Garia Bay. The two groups cannot, lithologically, be correlated due to the variable intensity of deformation and metamorphism which has affected them. These deformational and metamorphic episodes can however be correlated. In both Groups the early deformational event results, at least in part, in recumbent folds. The associated metamorphism is post-tectonic rather than syntectonic and in the Harbour le Cou Group and reworked gneiss the grade decreases eastwards i.e., garnets are developed at Harbour le Cou but only biotite and muscovite at Garia Bay. The metamorphism of the Bay du Nord Group shows a similar decrease in grade eastwards with the development of garnets at Bay le Moine and biotite and muscovite at Garia Bay.

The fabric related to the second deformational event is the dominant fabric in both groups and is conformable in dip and strike in both Groups. The metamorphic grade is similar.

The third deformation results, in both groups, in a north-south trending, poorly developed fabric. The metamorphism in both is retrogressive and chlorite is developed.

It is therefore proposed that although the stratigraphic age of the two groups is not necessarily the same, they have both been subjected to the same deformational and metamorphic events. This correlation is not based on structural style, which, by itself, is a poor basis for correlation, (Park, 1969), but on the similarity of deformational and metamorphic events and the conformity of the trend of these events, between the two groups.

These correlations are important, not just on a local scale, but on a regional scale, since, if they are accepted as valid then the reworking deformations and associated metamorphism is, at the oldest a Devonian event. Thus the Acadian Deformation (there is no evidence to suggest that it is a Hercynian event, altough it can not be proved that it is not) in southwest Newfoundland can be subdivided into three phases, the earliest of which has resulted in recumbent folds which close to the southeast, and a garnet grade of metamorphism attained. To date, the Acadian Deformation in Newfoundland is recognised as a single event resulting in upright folds and has, associated with it, a low grade to retrogressive metamorphism. (This is similar to the last phase of deformation and metamorphism recognised in the study area). Elsewhere in the Appalachian Orogenic Belt i.e., Maine and New England (A. M. Hussey, 11 1968; Thomson *et al.*, 1968) a high grade polydeformational Acadian event is recognised and well documented.

CHAPTER 9

THE CAPE RAY FAULT ZONE

The Cape Ray Fault Zone is a mylonite zone up to 1 km. wide which separates the Cape Ray Complex to the west from the Port aux Basques Complex to the east. It is in part overlain by the metasedimentary Windsor Point Group. Narrow zones of intense deformation, related to the fault, occur up to 4 km. across strike on either side of the fault.

The main mylonite zone is a zone of intense deformation which strikes northeast, dips steeply to the southeast, and can be traced at least 80 km. inland from the coast. On the coast, and for 6 km. inland the mylonite is unconformably overlain by the Windsor Point Group. Inland from this the two basement Complexes are in juxtaposition and the fabrics in both are overprinted and totally obliterated within the fault zone.

The Windsor Point Group has been subjected to two periods of deformation and a later period of kink band formation. The earliest phase is the most intense and, close to the fault, results in a tectonic banding. The second phase is also intense close to the fault and tightly folds the earlier banding.

There are thus two distinct episodes of movement on the fault. The earlier and more important, brought the two Complexes together and resulted in the breakdown of the gneissic fabrics and the development of the mylonite fabric along the fault zone. Subsequently the fault was exhumed and the Windsor Point Group deposited. All the pebbles in the conglomerates are derived from the Cape Ray Complex, indicating that the western block was raised, relative to the eastern block, during the exhumation. Further movement on the fault resulted in the deformation of the Windsor Point Group.

The fault has a distinct topographic and magnetic expression from the coast to north of La Poile. It can not however, be definitely traced into the Ordovician and Silurian sequences of the Central Mobile Belt, suggesting that the formation of the mylonite zone is earlier than the Lower Palaeozoic rocks present there.

Southwards, the Fault is correlated with the Aspy Fault in Cape Breton. This latter fault is a zone of major displacement which separates two completely dissimilar basement terranes. (Weibe, 1972; Neale and Kennedy, (in press)). The basement to the west of the Aspy fault is similar, lithologically, to the Cape Ray Complex, but that to the east is unlike the Port aux Basques Complex. (K. Currie, pers. comm.) The Carboniferous Horton Group, which is affected by late movements on the Aspy Fault, could not be correlated lithologically, with the Windsor Point Group.

The geological history of the Cape Ray Complex, west of the Cape Ray Fault, is similar to that of the Long Range (Grenville) Complex in northwest Newfoundland i.e. Leucocratic gneiss intruded by early megacrystic granites and by post tectonic massive medium grained granites. (Clifford and Baird, 1962). This Complex is therefore included in the Grenville Basement of Western Newfoundland and, as such, constitutes the western margin of the Central Mobile Belt

The Port aux Basques Complex forms part of the curvilinear belt of high grade metamorphic rocks, the Eastern Crystalline Belt, which extends from Bonavista Bay in the north to Port aux Basques in the south. This belt forms the eastern margin of the Central Mobile Belt. (Williams *et al.*, 1974).

Williams *et al.*, (1970) interpretated the curvilinear nature of the Eastern Crystalline Belt as representing a large scale fold, the Hermitage Flexure, which was truncated by the Cabot fault, and attributed the disappearance of the Central Mobile Belt in southwest Newfoundland to movements on this fault. This work, and recent work to the north, in the Burlington Peninsula (M. J. de Wit, 1974), has shown that the Cabot fault is largely contained within the Grenville Basement of Western Newfoundland, and that the Hermitage Flexure is truncated, not by the Cabot Fault but by the Cape Ray Fault Zone.

In northern Newfoundland the Central Mobile Belt contains Lower Ordovician rocks in its central part which are interpretated as remnants of an old ocean floor. (Upadhyay *et al.*, 1971; Strong, 1972; Strong, 1973). These rocks, and the entire Central Mobile Belt are not present in southwest Newfoundland, and the eastern and western margins of the Central Mobile Belt are juxtaposed along the trace of the Cape Ray Fault Zone.

Incomplete closure of this ancient ocean in northeast Newfoundland led to the preservation of ophiolite suites in the central part of the Central Mobile Belt. It is suggested that complete closure of this ocean in southwest Newfoundland led to the juxtaposition of the eastern and western margins of the ocean along the trace of the

Cape Ray Fault Zone. The fault is therefore of fundamental importance and is interpreted as a cryptic suture.

CHAPTER 10

GEOLOGICAL HISTORY OF THE AREA

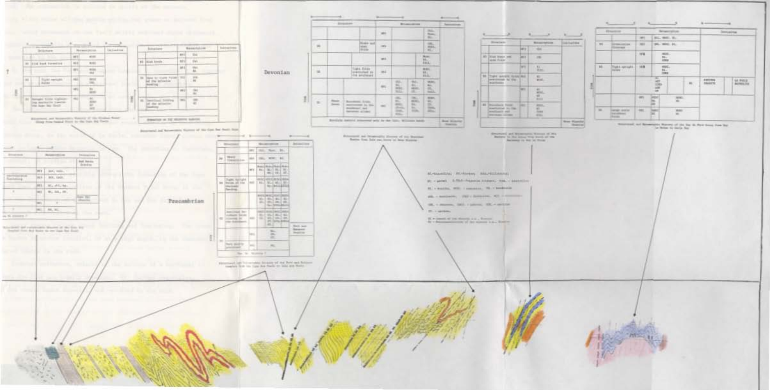
The geological history of the area is described in terms of sucessive structural and metamorphic events. For each group of rocks these events are summarised in table form. These tables are brought together in one diagram. This diagram (Table 9) is a complete geological history of the area. In this chapter the relationships between the groups are discussed.

The Cape Ray Complex and the Port aux Basques Complex form the oldest rocks in the area. The Cape Ray Complex is correlated with the Longe Range Gneiss of western Newfoundland, (Jukes, 1843; Murray and Howley, 1881; Gillis, 1972, Brown, 1973), and is thus thought to be Precambrian in age. The age of the Port aux Basques Complex is unknown and the structures within it can not be correlated with those in the Cape Ray Complex. However, the structural complexity, and the high grade, of these gneisses is indicative of a possible Pre-Cambrian age.

Both Complexes are further deformed and metamorphosed. These later events involve younger cover sequences. In the west, the Cape Ray and Port aux Basques Complexes are mylonitised and retrogressed along the trace of the Cape Ray Fault Zone. The fault can be traced up to 80 km. inland and has a distinct topographic and magnetic expression along its legth. However, it loses its continuity under the Ordovician and Silurian sequences of Central Newfoundland. This may indicate a pre or early Ordovician age for the initial formation of the Cape Ray Fault Zone.

Table 9

Geological History of the Area



The fault was subsequently exhumed and the Windsor Point Group deposited. The exhumation is related to uplift of the western, Grenville, block since all the debris within the group is derived from the west. Later movements on the fault mildly deformed these sediments. Unfortunately no fossils were found and therefore no stratigraphic age can be assigned to the group.

In the west the Port aux Basques Complex is reworked i.e. further deformed and metamorphosed, on a regional scale. This reworking infolds into the gneisses, a sequence of cover rocks, the Harbour le Cou Group. The structures resulting from this reworking can be traced eastwards into a second sequence of cover rocks, the Bay du Nord Group. This latter Group, to the north of La Poile, contains fossil plants which are Lower to Lower Middle Devonian in age. The reworking is therefore, at the oldest, an Acadian event.

No correlation is possible between the formation of the Cape Ray Fault Zone and the deposition of the Windsor Point Group in the west and the deposition of the Harbour le Cou and Bay du Nord Groups and subsequent deformation in the east.

Later events include minor faulting and fracturing. The trend of the faults is either parallel, or at a high angle, to the dominant banding or fabric in the rock.

Terminal morraines, related to the retreat of a northwest to southeast ice flow are locally observed. No further deposition, except for recent beach deposits, are recorded in the area.

CHAPTER 11

REGIONAL EVALUATION

The framework for the geological evolution of Newfoundland in the Lower Paleozoic is based, to a great extent, on detailed studies in north and northeast Newfoundland. (Williams *et al.*, 1972, 1974; Kennedy, 1973; Strong, 1974). Although two of the essential elements of this framework i.e. the Western Platform and the Eastern Crystalline Belt, can be extrapolated to the southwest coast, the lack of detailed geological data in Central Newfoundland makes any comparisons between the north and south extremely tenuous. It is however proposed to take a generalised framework from the north and use it as a template for the southwest coast and hence assess the possible continuity of the framework from the north to the south.

In the north the Western Platform and the Eastern Crystalline Belt are separated by Ordovician and Silurian sequences within which relicts of oceanic crust, the Proto-Atlantic (Wilson, 1966), are recognised. (Upadhyay *et al.*, 1971; Strong, 1972; Strong, 1973). Similar ophiolite suites are recognised on the west coast and are interpretated as obducted remnants of a Pre Middle Ordovician ocean basin in north Newfoundland. (Church and Stevens, 1971; Williams, 1971, Williams and Malpas, 1972; Malpas, 1973; Malpas and Strong, in press). This obduction is related to closure of the ocean basin by subduction. A westward dipping subduction zone has been proposed by Dewey (1969), Dewey and Bird (1971) and Kennedy (1973). However Church and Stevens (1971), and Strong (1973, 1974) suggest that it was eastward dipping.

In southwest Newfoundland the Western Platform and the Eastern Crystalline Belt are juxtaposed along the trace of the eastward dipping Cape Ray Fault Zone. This fault is interpretated as a cryptic suture along which complete closure of the ocean to the north has taken place (this thesis, Brown, 1973; Dewey and Kidd, 1974). Thus the subduction zone related to the closure must, in southwest Newfoundland, have dipped to the east (c.f. Dewey and Burke, 1973).

This interpretation of the Cape Ray Fault Zone implies that remnants of oceanic crustal material, or continental margin deposits may be present either within the fault zone, or as thrust slices to the west of the fault zone, depending upon the level of exposure (Dewey and Burke, 1973). Such remnants were not found within the fault zone. However, 10 km. northwest of the fault zone, outwith the map area, in the Long Range Gneiss, Phair (1949) described an entirely fault bounded mafic to ultramafic body, the Long Range Mafic Complex. Although no intrusive relationships were recorded he interpretated the body as a lopolith. On a petrological basis the Long Range Mafic Complex was likened to the Bay of Islands Complex in Western Newfoundland. This latter Complex has since been interpretated as an obducted ophiolite (Williams, 1971; Williams and Malpas, 1972; Malpas, 1973; Malpas and Strong, in press). The similarities in rock types and succession of rock types between the two Complexes and an oceanic crustal section (Table 10) is indicative of a possible oceanic origin for the Long Range Mafic Complex.

The only other possible subduction related phenomena recognised in southwest Newfoundland is the Rose Blanche Granite. This type of

Table 10

Comparison of rock types from the Long Range Mafic Complex and the Bay of Islands Complex with oceanic crystal equivalents.

Long Range Mafic Complex. After Phair (1949)	Bay of Islands Complex. After Malpas (1973)			Oceanic Crystal Equivalents
	Sediments			Layer 1
	Pillow lavas			
	Sheeted dykes and dyke breccias		Cumulates	Layer 2
Hornblende Gabbro	Gabbro			Layer 3
Anorthosite and Gabbroic Anorthosite	Anorthosite, Troctolite	Critical Zone		Moho
Interbanded Zone	Feldspathic Dunite			
Peridotite with chromite and green spinel	Dunite with chromite			Petrological Moho
Dunite with chromite	Harzburgite		Mantle Tectonites	
	Enstatolite			
	Lherzolite			

granite i.e. leucocratic garnet bearing, is thought to be either a product of partial melting of a downthrust lithosphere in a subduction zone (Green and Ringwood, 1972; Fitton, 1972; Brousse and Bijouard, 1972) or the product of partial melting of sialic material (Joyce, 1973; Best *et al.*, 1974; Birch and Gleadow, 1974). Dewey and Burke (1973) combine these two possible origins and suggest that this type of granite is formed by partial melting of the downthrust lithosphere resulting in a calc alkaline magma which, when rising through the overlying continental crust, partially melts that crust and becomes contaminated. The Rose Blanche Granite occurs to the east of the Cape Ray Fault Zone indicating again that the subduction zone was eastward dipping in southwest Newfoundland. It is worthy of note that garnetiferous granites are not restricted to the southwest coast but are found throughout the entire Eastern Crystalline Belt (Williams, 1967; Kennedy and McGonigal, 1973; Colman-Sadd, 1974; Strong *et al.*, 1974).

There is thus a compatibility between the marginal gneissic basements in northern Newfoundland and the basements separated by the Cape Ray Fault Zone in southwest Newfoundland. Comparison of the cover rocks however, shows that there are major differences between the two areas:

(a) The entire Ordovician and Silurian sequences of the Central Mobile Belt in the north, are not present in the southwest.

(b) The polyphase deformation of the western and eastern margins of this old ocean i.e., Burlingtonian and Ganderian (Kennedy, in press), is not recognised in the southwest.

(c) The main polyphase deformational event (post formation of the gneisses) in the southwest is Acadian (or Hercynian ?). Such polyphase Acadian deformation is only locally observed in the north.

(d) The metamorphic grade associated with this Acadian event in the southwest is high i.e., garnet and locally sillimanite. This is not recognised in the north.

Thus the framework, evolved in the north, has corollaries in southwest Newfoundland prior to the closure of the Proto-Atlantic ocean. After this closure the two areas are distinctly dissimilar. This may best be explained by complete closure in the southwest along the trace of the Cape Ray Fault zone and only partial closure in the north.

BIBLIOGRAPHY

Aeromagnetic Series,. 1970. Geophysics Paper 4503. Port aux Basques, Newfoundland.

_______ 1970. Geophysics paper 4490. Grandy's Lake, Newfoundland.

Appleyard, Edward C. 1974. Basement/Cover Relationships within the Grenville Province in Eastern Ontario. Can. J. Earth-Sci., VII, No. 3, pp. 369-379.

Barrow, C. 1893. On an Intrusion of Muscovite-Biotite Gneiss in the Southeastern Highland of Scotland and its Accompanying Metamorphism. Quart. Journ. Geol.Soc. Lond, V. 49, pp.330-358.

_______ 1912. On the Geology of the Lower Dee-side and the Southern Highland Border. Proc. Geol. Assoc. Lond. V.23, pp. 268-284.

Beach, A., M. P. Coward and R. H. Graham. 1974. An Interpretation of the Structural Evolution of the Laxford Front, North-west Scotland. Scott. J.Geol., V. 9, pt, 4, pp. 297-308.

Beach, A. 1974. The Measurement and Significance of Displacements on Laxfordian Shear Zones, North-west Scotland. Proc. Geol. Ass., V. 85, pt. 1, pp. 13-21.

Best, M. G., Armstrong, R. L., Graustein, W. C., Embree, G. F. and Ahlborn, R. C. 1974. Mica Granites of the Kean Mountain Pluton Eastern White Pine County, Nevada: Remobilised Basement of the Cordilleran Miogeosyncline? Geol. Soc. Am. Bull., V. 85, No. 8, pp.1277-1286

Birch, W. D. and Gleadow, A. J. W. 1974. The Genesis of Garnet-Cordierite in Acid Volcanic Rocks: Evidence from the Cerberean Cauldron, Central Victoria, Australia. Cont. Min. Pet., V. 45, PP. 1-13.

Bridgewater, D., Escher, A. and Watterson, J. 1973. Tectonic Displacements and Thermal Activity in two contrasting Proterozoic Mobile Belts from Greenland. Phil. Trans. R. Soc Lond. A., V. 273, pp. 513-533.

Brousse, R. et Bizouard, H. 1972. Grenats des Andésites et des Rhyolites de Slavaquie, origine des Grenats dans les Series Andésitiques. Cont. Min. Pet., V. 35, pp. 201-213.

Brown, P. A. 1972. Structural and Metamorphic History of the Gneisses of the Port aux Basques region, Newfoundland. Msc. thesis, Memorial Univ., unpubl.

Brown, P. A. 1973. Possible Cryptic Suture in Southwest Newfoundland. Nature Physical Science, V. 245, No. 140, pp. 9-10.

Brown, P. E. 1967. Loch Coire Migmatites. Cont. Min. Pet., V. 14, No. 1, pp. 1-26.

Cannon, R. T. 1963. Classification of Amphibolites. Geol. Soc. Am. Bull., V. 74, pp. 1087-1088.

Christie, J. M. 1960. Mylonitic Rocks of the Moine Thrust-Zone in the Assynt Region, North-west Scotland. Edin. Geol. Soc. Tr. V. 18, pt. 1, pp. 79-93.

Church, W. R. and Stevens, R. K. 1971. Early Paleozoic Ophiolite Complexes of the Newfoundland Appalachians as Mantle-Oceanic Crust Sequences. J. Geophys. Res., V. 76, pp. 1460-1466.

Clifford, P. M. and Baird, D. M. 1962. Great Northern Peninsula of Newfoundland-Grenville Inlier. Can. Inst. Mining and Metallurgy Trans., V. 65, pp. 95-102.

Colman-Sadd, S. P. 1974. Geologic Development of the Bay d'Espoir Area, Southeastern Newfoundland. Unpubl. PhD thesis. M.U.N.

Cooper, J. R. 1954. LaPoile - Cinq Cerf Map Area, Newfoundland. Can. Geol. Survey Mem. 276.

Coward, M. P., Graham, R. H., James, P. R. and Wakefield, J. 1973. A Structural Interpretation of the Northern Margin of the Limpopo Orogenic Belt, Southern Africa. Phil. Trans. R. Soc. Lond. A., V. 273, pp. 487-491.

Cummins and Shackleton. 1955. 'The Ben Lui Recumbent Syncline (S.W. Highlands). Geol. Mag., V. 92, pp. 353-363.

Deer, Howie and Zussman. 1966. An Introduction to the Rock Forming Minerals. Longmans, Gran and Co. Ltd., London.

Dewey, J. F. 1969. The Origin and Development of Kink Bands in a Foliated Body. Geol. J., V. 6, pt. 2, pp. 193-216.

——— 1969. Evolution of the Appalachian/Caledonian Orogen. Nature Vol. 222. PP. 124-129.

Dewey, J. F. and Bird, J. M. 1971. Origin and Emplacement of the Ophiolite Suite - Appalachian Ophiolites of Newfoundland. J. Geophys. V. 76. pp. 3170-3206.

Dewey, J. F. and Burke, K. 1973. Tibetan, Variscan and Precambrian Basement Reactivation: Products of Continental Collision. Journ. Geol. V: 81 No. 6, pp. 683-692.

Dewey, J. F. and Kidd, W. S. F. 1974. Continental Collisions in the Appalachian-Caledonian Orogenic Belt: Variations related to Complete and Incomplete Suturine. Geology, V.2, No. 11, pp. 543-546.

Dietrich, R. W. 1960. Banded Gneisses. Journ. Petrol., V. 1, pp. 99-120.

Dorf, E. and Cooper, J. R. 1943. Early Devonian Plants from Newfoundland. Journ. Paleo. V. 17. No. 3. pp. 264-270.

Fitton, J. G. 1972. The Genetic Significance of Almandine-Pyrope Phenocrysts in the Calc-Alkaline Borrowdale Volcanic Group, Northern England. Cont. Min. Pet. V. 36. pp. 231-248.

Fleuty, M. J. 1964. The Description of Folds. Geologists Assoc. Lond. Pr. V. 75. pt. 4. pp. 461-492.

Flinn, D. 1962. On Folding during Three Dimensional Progressive Deformation. Quart. Journ. Geol. Soc. Lond. V. 118. pp. 385-433.

______ 1965. Deformation in Metamorphism in Controls of Metamorphism. Oliver & Boyd. pp. 46-69.

Gale, G. H. 1965. Economic Study of Pegmatites in Newfoundland. Newfoundland Dept. Mines, unpubl. report.

Gillis, J. W. 1965. Age Determinations and Geological Studies in Wanless, R. K., Stevens, R. D., Lachance, C. R. and Rimsaite, R. Y. H. Geol. Surv. Can. paper 64-17 (part 1), pp. 112-113.

______ 1967. Age Determinations and Geological Studies in Wanless, R. K., Stevens, R. D., Lachance, C. R. and Rimsaite, R. Y. H. Geol. Surv. Can. paper 64-17 (part 1). pp. 109-112.

______ 1972. Geology of Port aux Basques Map-Area, Newfoundland. Report and Map 1340A, Geol. Surv. Can.

Green, T. H. and Ringwood, A. E. 1972. Crystallisation of Garnet Bearing Rhyodacite under High Pressure Conditions. J. Geol. Soc. Aust. V. 19. pp. 203-212.

Harker, A. 1950. Metamorphism. London, Methuen, 362p.

Harris, A. L. and Rast, N. 1960. The Evolution of Quartz Fabrics in the Metamorphic Rocks of Central Perthshire. Trans. Edin. Geol. Soc. V. 18. p. 51.

Hepworth, J. V. 1967. The Photogeological Recognition of Ancient Orogenic Belts in Africa. Geol. Soc. Lond. Quart. J., V. 123. pt. 3. No. 491. pp. 253-290.

Higgins, M. W. 1971. Cataclastic Rocks. Geol. Surv. Spec. paper 687.

Holmes, A. 1920. Nomenclature of Petrology. T. Musby & Co., London.

Hussey II, A. M. 1968. Stratigraphy and Structure of Southwestern Maine: in Studies of Appalachian Geology, northern and maritime. pp. 291-301. Intersci. Publ., New York.

Jukes. 1843. General Report of the Geological Survey of Newfoundland, 1839-1840. London.

Joyce, A. S. 1973. Chemistry of the Minerals of the Granitic Murrumbidgee Batholith, Australian Capital Territory. Chem. Geol. V. 11, pp. 271-296.

Kalsbeek, F. 1965. On the Origin of Some Banded Amphibolites and Gneisses in the Belledonne Massif (French Alps). N. Jb. Miner. Alh. V. 2. pp. 171-188.

Katz, M. B. 1970. Banded Gneisses. Thickness Distribution of Layers and their Lithologic Transitions. Lithos. V. 3. pp. 1-13.

Kay, Marshall and Colbert, E. H. 1965. Stratigraphy and Life History. New York, John Wiley, 736p.

Kay, Marshall. 1967. Stratigraphy and Structure of Northeastern Newfoundland Bearing on Drift in North Atlantic. Am. Assoc. Petroleum Geologists Bull. V. 51. pp. 579-600.

Kennedy, M. J. and McGonigal, M. 1972. The Gander Lake and Davidsville Groups of Northeastern Newfoundland. Can. J. Earth Sci. V. 9. pp. 452-459.

Kennedy, M. J. 1973. Pre-Ordovician Polyphase Structure in the Burlington Peninsula of the Newfoundland Appalachians. Nature Phys. Sci. Vol. 240. No. 110. pp. 114-116.

Kennedy, M. J. in Press. Repetitive Orogeny in the Northeast Appalachians New Plate Models based upon Newfoundland Examples. Tectonophysics.

Kretz, R. 1960. Preliminary Examination of Quartz-Plagioclase Layers and Veins in Amphibolite Facies Gneisses, Southwestern Quebec. Proceed. Geol. Assoc. Can. V. 12. pp. 23-43.

______ 1964. Analyses of Equilibrium in Garnet-Biotite-Sillimanite Gneisses from Quebec. Journ. Pet. V. 5. pp. 1-20.

______ 1966. Interpretation of the Shape of Mineral Grains in Metamorphic Rocks. J. Pet. V. 7. pt. 1. pp. 68-94.

Malpas, J. G. 1973. A Restored Section of Oceanic-Crust and Mantle in Western Newfoundland. Geol. Soc. Am. N.E. Sect. abstract.

Malpas, J. G. and Strong, D. F. in Press. A Comparison of Chrome Spinels in Ophiolites and Mantle Diapirs of Newfoundland. Geochem Cosmochem. Acta.

Mason, R. 1973. The Limpopo Mobile Belt-Southern Africa. Phil. Trans. R. Soc. Lond. A. V. 273. pp. 463-48[illegible].

Miyashiro, A. 1961. Evolution of Metamorphic Belts. Journ. Pet. V. 1-2. pp. 277-311.

Murray, A. and Howley, J. P. 1881. Report of the Geological Survey of Newfoundland for 1866-1880. Stanford.

Neale, E. R. W. 1965. Age Determinations and Geological Studies in Wanless, R. K., Stevens, R. D., Lachance, C. R. and Rimsaite, R. Y. H. Geol. Surv. Can. paper 64-117 (part 1), pp. 115-116.

Neale, E. R. W. and Kennedy, M. J. (in press). Basement and Metamorphosed Cover Rocks at Cape North, Cape Breton Island, Nova Scotia.

Olesen, N, Ø. 1971. The Relative Chronology of Fold Phases, Metamorphism and Thrust Movements in the Caledonides of Troms, North Norway. Norsk. Geol. Tiddskrift. V. 51. No. 4. pp. 355-377.

Park, R. G. 1969. Structural Correlations in Metamorphic Belts. Tectonophysics . V. 7. No. 4. pp. 323-338.

Phair, George. 1949. Geology of the Southwestern Part of the Long Range, Newfoundland. Ph.D. thesis, Princeton Univ., unpubl.

Power, W. R. 1955. The South Coast of Newfoundland in and around the Villages of Isle aux Morts and Burnt Islands. Report on summers field work part I, Newf. Dept. Mines and Resources, Mines Branch, unpubl.

Ramsay, J. G. 1967. Folding and Fracturing of Rocks. McGraw-Hill. 568 p.

Ramsay, J. G. and Graham, R. H. 1970. Strain Variation in Shear Belts. Can. Journ. Earth. Sci. V. 7. pp. 786-813.

Rast, N. and Sturt, B. A. 1957. Crystallographic and Geological Factors in the Growth of Garnets from Central Perthshire. Nature, Lond. V. 179. p. 215.

Rast, N. 1965. Nucleation and Growth of Metamorphic Minerals in Controls of Metamorphism, Oliver and Boyd. pp. 73-96.

Rast, N. 1966. Recrystallisation of Mica in Crenulated Schists. Nature V. 210, p. 5037.

Reineck-Singh. 1973. Depositional Sedimentary Environments. Springer-Verlag, New York.

Reverdatto, V. V. 1973. The Facies of Contact Metamorphism. Ed. S. Sobolev. Trans. D. A. Brown.

Riley, G. C. 1962. Stephenville Map Area, Newfoundland. Geol. Surv. Can. Mem. 323.

Shackleton. 1958. Downward Facing Structures of the Highland Border. Quart. J. Geol. Soc. Lond. V. 113 (1957) pp. 361-392.

Spry, A. 1969. Metamorphic Textures. Pergamon Press.

Strong, D. F. 1972. Sheeted Diabases of Central Newfoundland: New Evidence for Ordovician Seafloor Spreading. Nature, V. 235, No. 5333 pp. 102-104.

_______ 1973. Plate Tectonic Setting of Appalachian-Caledonian Mineral Deposits as indicated by Newfoundland Deposits. Soc. Min. Eng. Preprint No. 73-1-320. pp. 1-31.

_______ 1973. Lushs Bight and Roberts Arm Groups of Central Newfoundland Possible Juxtaposed Oceanic and Island-Arc Volcanic Suites. Geol. Soc. Am. Bull. V. 84. pp. 3917-3928.

_______ 1974. Metallogeny and Plate Tectonics: A Guidebook to Newfoundland Mineral Deposits. Nato Advanced Studies Inst. p. 171.

Strong, D. F., Dickson, W. L., O'Driscoll, C. F. and Kean, B. F. 1974. Geochemistry of Eastern Newfoundland Granitoid Rocks. Dept. Mines and Energy, Mineral Development Division Report 74-3.

Sturt, B. A. and Harris, A. L. 1961. The Metamorphic History of the Loch Tunnel Area, Central Perthshire, Scotland. Lpool. and Manchester Geol. J., V. 2, pt. 4, pp. 689-711.

Sutton, J. and Watson, J. 1951. The Pre-Torridonian Metamorphic History of the Loch Torridon and Scourie Areas in the Northwest Highlands and its Bearing on the Chronological Classification of the Lewisian. Quart. J. Geol. Soc. Lond., V. 106, pp. 241-296.

Sutton, J. S. 1972. The Precambrian Gneisses and Supracrustal Rocks of the Western Shore of Kaipokok Bay, Labrador, Newfoundland. Can. Journ. Earth Sci., V. 9, No. 12, pp. 1677-1692.

Talbot, C. J. 1970. The Minimum Strain Ellipsoid using Deformed Quartz Veins. Tectonophysics, V. 9, pp. 47-76.

Thompson, James B. Jr., Robinson, Peter, Clifford, Tom. 1968. Nappes and Gneiss Domes in West-Central New England. in Studies in Appalachian Geology, northern and maritime, pp. 319-327. Intersci. Publ., New York.

Turner, F. J. 1968. Metamorphic Petrology. McGraw Hill.

Upadhyay, H., Dewey, J. F. and Neale, E. R. W. 1971. The Betts Cove Ophiolite Complex, Newfoundland: Appalachian Oceanic Crust and Mantle. Geol. Assoc. Canada Proc., V. 24, pp. 27-36.

Vance, J. A. 1961. Polysynthetic Twinning in Plagioclase. Am. Min., V. 46, pp. 1097-1119.

Vernon, R. H. 1968. Microstructure of High Grade Metamorphic Rocks at Broken Hill, Australia. J. Pet., V. 9, pp. 1-22.

Voll, G. 1960. New Work on Petrofabrics. Liverpool and Manchester Geol. J., V. 2, pp. 503-547.

Watson, J. 1973. Effects of Reworking on High Grade Gneiss Complexes. Phil. Trans. R. Soc. Lond. A., V. 273, pp. 443-455.

Watterson, J. 1968. Homogeneous Deformation of the Gneisses of Vesterland, South-west Greenland. Meddr. Gronland. Bd., 175, No. 6.

Weibe, R. A. 1972. Igneous and Tectonic Events in Northeastern Cape Breton Island, Nova Scotia. Can. Journ. E. Sci., V. 9, No. 10, pp. 1262-1277.

Whitten, E. H. T. 1966. Structural Geology of Folded Rocks. Rand McNally & Co.

Williams, H. 1964a. The Appalachians in Northeastern Newfoundland - A Two-sided System. Am. Jour. Sci., V. 262, pp. 1137-1158.

Williams, H. (compiler). 1967. Island of Newfoundland. Geol. Surv. Can., Map 1231a.

Willaims, Harold, Kennedy, M. J. and Neale, E. R. W. 1970. The Hermitage Flexure, The Cabot Fault and the Disappearance of the Newfoundland Central Mobile Belt. Geol. Soc. Amer. Bull., V. 81, pp. 1563-1568.

Willaims, H. 1971. Mafic-Ultramafic Complexes in Western Newfoundland and the Evidence for their Transportation. Geol. Assoc. Can. Proc., A. Nfld. Decade, V. 24, No. 1, pp. 9-25.

Williams, H., Kennedy, M. J. and Neale, E. R. W. 1972. The Appalachian Structural Province: in Variations in Tectonic Styles in Canada. Eds. Price, R. A. and Douglas, R. J. W., Geol. Assoc. Can. Spec. Paper No. 11, 1973.

Williams, H. and Malpas, J. G. 1972. Sheeted Dykes and Brecciated Dyke Rocks within Transported Igneous Complexes, Bay of Islands, Western Newfoundland. Can. J. Earth Sci., V. 9, pp. 1216-1229.

Williams, H., Kennedy, M. J. and Neale, E. R. W. 1974. The Northeastward Termination of the Appalachian Orogen. in The Ocean Basins and Margins, Vol. 2, Ed. by A. E. M. Nairn and F. G. Stehli, Plancum Pub. Co., New York.

Williams, P. F. 1972. Development of Metamorphic Layering and Cleavage in Low Grade Metamorphic Rocks at Bermacui, Australia. Am. Journ. Sci., V. 272, pp. 1—47.

Williamson, W. O. 1935. The Composite Gneiss and Contaminated Granodiorite of Glen Shee, Perthshire. Geol. Soc. Lond. Q. J., No. 363, V. 91, pp. 382—419.

Wilson, G. 1961. The Tectonic Significance of Small Scale Structures and their Importance to the Geologist in the Field. Annales. Soc. Geol. Belg., V. 84, pp. 423—458.

de Wit, M. J. 1974. On the Origin and Deformation of the Fleur de Lys Metaconglomerate, Appalachian Fold Belt, Northwest Newfoundland. Can. Journ. E. Sci., V. 11, No. 8, pp. 1168-1180.

Wynne-Edwards, H. R. 1972. The Grenville Province: in Variations in tectonic styles in Canada (R. A. Price and R. J. W. Douglas, Eds.), Geol. Am. Can., Spec. Pap. 11, pp. 264-334.

Zwart, H. J. 1960. The Chronological Succession of Folding and Metamorphism in the Central Pyrenees. Geol. Rundschau, V. 50, pp. 203-218.

_____ 1962. On the Determination of Polymetamorphic Mineral Associations and its Application to the Bosost Area (Central Pyrenees). Geol. Rundschau, V. 52, pp. 38-65.

APPENDIX I

ORIGIN OF GARNETS IN THE ROSE BLANCHE GRANITE

Garnets are scattered throughout the Rose Blanche Granite. The crystals are light pink in colour and generally less than 2 mm. in diameter. They are a minor accessory mineral of the granite and only one or two were observed per outcrop. No noticeable increase in garnet content was noted close to the granite margins, even where the surrounding metamorphic rocks contain garnet bands. Late leucocratic dykes associated with granite do however contain up to 2 modal percent garnet. The margins of the dykes locally show a garnet rich-garnet poor banding. The bands are up to 5 cms. in width, are parallel to the contact and are folded by the regional deformational events.

In thin section the garnets are seen to be anhedral to subhedral and generally occur as an interstitial mineral at grain boundaries and triple junctions. Locally they are embayed and contain inclusions of quartz. Several garnet crystals were found included in strained feldspars.

Calculations from x ray diffraction tracings give the unit cell dimensions a = 11.57-11.58 Å. Their refractive index = 1.81. Using determination charts for garnets (Deer, Howie and Zussman, 1966) these data indicates that the garnets are almandine rich.

Almandine rich garnets in felsic extrusive and intrusive rocks have been documented since the turn of the century and two hypothesis for their origin have been proposed i.e., igneous or metamorphic.

Sorby (1880), Marr (1900) and Harker (1902) suggested that they were igneous in origin but the latter two later changed their opinion and stated that a metamorphic origin was more likely. Walker (1904) and Green (1915) both thought that the garnets were igneous in origin but that they were due to a late 'solfataric stage' of volcanism. Hadfield and Whiteside (1936) noted that many of the garnets were broken down and resorbed by the granite and therefore proposed that their formation was the result of an earlier metamorphic event and that their presence in the granite was due to the assimilation of garnet bearing xenoliths. More recently Oliver (1956) and Binns (1966), from petrographic data, favoured an igneous origin whilst Makarov and Suprychev (1964) and Zeck (1970) favoured assimilation of garnet bearing xenoliths by the felsic magma.

Recent experimental work by Green and Ringwood (1968a, 1968b and 1972) has shown that garnets occur on and near the liquidus in calc alkaline rocks at high pressure and that they may be an early crystallisation product in a calc alkaline magma. Microprobe analysis of the garnets both experimental and naturally occurring, indicate that they are always almandine rich. The experimental garnets were however always more grossular rich than the naturally occurring garnets, suggesting that natural conditions were not duplicated.

Electron microprobe investigations have shown that there are significant differences in composition between igneous garnets and the metamorphic garnets in the surrounding metamorphic rocks. Warren (1970) found that igneous garnets from a quartz diorite stock in British Columbia are either homogeneous, or are zoned with Fe markedly decreasing from core to rim amd Mn constant. The metamorphic garnets contained within the surrounding envelope of metamorphic rocks, are zoned with Fe markedly increasing and Mn decreasing from core to rim. Birch and Gleadow (1974) showed that igneous garnets from the Cereberean Cauldron, Central Victoria, Australia, contained Fe Mn rich cores and Mg Ca rich rims, and that the metamorphic garnets in the surrounding metamorphic rocks had the reverse zonation i.e., Fe Mn rich rims.

Fitton (1972) found that the igneous garnets from the Borrowdale Volcanic Group, England, had Fe rich cores and Mg rich rims. He also noted that the overall composition of the garnets was related to the composition of the magma in that Mg rich garnets were associated with andesitic compositions and Fe rich Mg poor garnets were associated with dacitic compositions. Broussé and Bijouard (1972) from garnets in Slovakian andesites and rhyolites, found a similar overall Fe enrichment trend with increasing acidity of the melt.

These results indicate that for a particular igneous body the garnets that crystallise from the melt can be differentiated from 'restite' metamorphic garnets by the different zonation patterns of Fe, Mg, Mn and Ca. However, the igneous garnet composition is related to the composition of the melt and therefore the type of zonation is closely linked to the crystallisation history of that melt. Thus no 'type' igneous zonation pattern is likely, although Fe rich cores and Fe poor rims appear to be common.

Backscatter photographs of one garnet from the Rose Blanche granite and two garnets from the surrounding metamorphic rocks failed to show any 'type' zonation pattern which could be used to distinguish between those of an igneous, and those of a metamorphic origin. The garnets in the granite are however thought to be igneous in origin since:

1) They are uniformly distributed throughout the main granite body and show no marked increase close to the contacts, even where metamorphic garnets are abundant in the surrounding rocks.

2) Fragments of gneiss which contain garnet-quartz bands occur as xenoliths in the granite and show little sign of resorption. There is no increase in garnet abundance around these xenoliths.

3) The garnets are concentrated in late leucocratic dykes.

4) A pre metamorphic garnet rich-garnet poor banding occurs locally at the margins of the leucocratic dykes and parallels the contact. A similar type of banding was found in one pegmatite within the granite.

5) The garnets are generally inclusion free, unlike most metamorphic garnets. (Plate 81).

6) Garnets occur as inclusions within microcline crystals. (Plate 81).

7) The abundance of garnets throughout the granite sheets bears no relationship to the grade of metamorphism i.e., they are present where the granite is almost undeformed and the metamorphism is retrogressive, and where the granite contains two tectonite fabrics and sillimanite is developed in the surrounding metamorphic rocks.

The petrogenesis of these garnet bearing granitic rocks has been little studied. Green and Ringwood (1972), from experimental work, suggest that the magma is formed by partial melting of a downthrust lithosphere in subduction zones, and that garnet is an early high pressure crystallisation phase. Fitton (1972) and Brousse and Bijouard (1972) concur with this origin and suggest that garnet is a high pressure phase since at low pressures, hornblende and not garnet, would be the mafic phase.

Birch and Gleadow (1974), Best *et al.*, (1974), and Joyce (1973) suggest that the magma is generated by partial melting of sialic material i.e., remobilisation of basement. These authors all describe the composite nature of the intrusives and Joyce (1973), from partition coefficients of gallium in feldspars, has shown that the garnetiferous leucocratic granite phase is a low temperature late stage crystallisation product of the composite body.

The Rose Blanche Granite is associated with the reworking of the Port aux Basques Gneiss and thus the second of the two possible origins is quite feasible. However, the interpretation of the Cape Ray Fault Zone as a cryptic suture makes association of the granite with subduction quite likely. Following Dewey and Burke (1973), it is proposed that the granite is a product of both the above mechanisms in that eastward dipping subduction (Strong, 1973, 1974) along the trace of the Cape Ray Fault Zone resulted in partial melting of the downthrust lithosphere to give a calc alkaline magma which, when rising through the overlying gneisses, partially melted these gneisses and became contaminated. The intrusion took place during, or just prior to, the reworking of the gneisses.

BIBLIOGRAPHY

Best, M. G., Armstrong, R. G., Graustein, W. C., Embree, G. F. and Ahlborn, R. C. 1974. Mica Granites of the Kern Mountain Pluton Eastern White Pine County, Nevada; Remobilised Basement of the Cordilleran Miogeosyncline? Geol. Soc. Am. Bull., V. 85, No. 8, pp. 1277-1286.

Binns, R. A. 1966. Granitic Intrusions and Regional Metamorphic Rocks of Permian Age from Wonguibinoa District, North-Eastern New South Wales. J. Proc. Roy. Soc. New S. Wales, V. 99, pp. 5-36.

Birch, W. D. and Gleadow, A. J. W. 1974. The Genesis of Garnet-Cordierite in Acid Volcanic Rocks: Evidence from the Cerbergan Cauldron, Central Victoria, Australia. Cont. Min. Pet., V. 45, pp. 1-13

Brousse, R. et Bijouard, H. 1972. Grenats des Andésites et des Rhyolites de Slavaquie, Origine des Grenats dans les Series Andésitiques. Cont. Min. Pet., V. 35, pp. 201-213.

Dewey, J. F. and Burke, K. 1973. Tibetan, Variscan and Precambrian Basement Reactivation: Products of Continental Collision. Journ. Geol., V. 81, No. 6, pp. 683-692.

Fitton, J. G. 1972. The Genetic Significance of Almandine-Pyrope Phenocrysts in the Call-Alkaline Borrowdale Volcanic Group, Northern England. Cont. Min. Pet., V. 36, pp. 231-248.

Green, J. F. N. 1915. The Garnets and 'Streaky' Rocks of the English Lake District. Min. Mag., V. XVII, pp. 207-217.

Green, T. H. and Ringwood, A. E. 1968a. Genesis of the Calc-Alkaline Igneous Rock Suite. Cont. Min. Pet., V. 18, pp. 105-162.

_______ 1968b. Origin of Garnet Phenocrysts in Calc-Alkaline Rocks. Cont. Min. Pet., V. 18, pp. 163-174.

_______ 1972. Crystallisation of Garnet Bearing Rhyodacite under High Pressure Conditions. J. Geol. Soc. Aust., V. 19, pp. 203-212.

Hadfield, G. S. and Whiteside, H. C. M. 1936. The Borrowdale Volcanic Series of High Rigg and Adjoining Low Rigg Microgranite. Proc. Geol. Soc., V. XLVII, pp. 42-64.

Harker, A. 1902. Notes on the Igneous Rocks of the English Lake District. Proc. Yorkshire Geol. Soc., V. 14.

Joyce, A. S. 1973. Chemistry of the Minerals of the Branitil Murrumbidgee Batholith, Australian Capital Territory. Chem. Geol. V. 11, pp. 271-296.

Makarov, N. N. and Suprychev, V. A. 1964. Xogenic Garnet (Pyrope-Almandine) from Volcanic Rocks of the Crimea. Doklady Akad. Nauk. U.S.S.R., Earth Sci. Sect., V. 157, pp. 64-67.

Marr, J. E. 1900. Notes on the Geology of the English Lake District. Proc. Geol. Assoc., v. XVI, pp. 449-483.

Oliver, R. A. 1956. The Origin of Garnets in the Borrowdale Volcanic Series and Associated Rocks. Geol. Mag., V. 93, pp. 121-139.

Sorby, H. C. 1880. Slates of the English Lake District: Part of Presidential Address. Quart. J. Geol. Soc., V. XXXVI, Proceedings, 74-75.

Strong, D. F. 1973. Lushs Bight and Roberts Arm Groups of Central Newfouldland: Possible Juxtaposed Oceanic and Island Arc Volcanic Suites. Geol. Soc. Am. Bull., V. 84, pp. 3917-3928.

_____ 1974. Geochemistry of Eastern Newfoundland Granitoide Rocks. Dept. Mines and Energy, Mineral Development Division, Report 74-3.

Walker, E. E. 1904. Notes on the Garnet Bearing and Associated Rocks of the Borrowdale Volcanic Series. Q. J. Geol. Soc. Lond., v. IX, pp. 70-105.

Warren, R. C. 1970. Electron Microprobe Investigations of Almandine Garnets from a Quartz Diorite Stock and Adjacent Metamorphic Rocks. B. C., 1 (Abstract), Trans. Am. Geophys. U., V. 51, p. 444.

Zeck, H. P. 1970. An Erupted Migmatite from Cerro de Hoyazo, S.E. Spain. Cont. Min. Pet., V. 26, pp. 225-246.

APPENDIX II

XONOTLITE: A NEW OCCURRENCE AT ROSE BLANCHE

Xonotlite ($Ca_6 Si_2 O_{17} (OH)_2$) was found in a hornfelsed calc silicate pod close to the contact with a garnetiferous leucocratic granite in the Rose Blanche - Harbour le Cou area. The mineral assemblage of the calc silicate is: wollastonite, vesuvianite, garnet, xonotlite, apatite, calcite and quartz. These minerals occur in bands which parallel the granite contact. Close to the contact bands consisting of radiating columnar aggregates of wollastonite, apatite and calcite predominate. These are succeeded by xonotlite - calcite and garnet - vesuvianite - apatite - calcite bands. Quartz occurs throughout the entire rock. Later regional deformational events retrogress this hornfels mineralogy.

The xonotlite occurs as massive stubby aggregates which are purple to dark pink on the fresh surface and weather to a light pink. In thin section the crystals were found to be extensively altered to a carbonate and the physical properties could not be determined. A positive identification was made by comparing X - Ray Diffraction tracings with data from A.S.T.M. cards.

The type occurrence of xonotlite is at Tetela de Xonotla, Mexico (Larsen, 1923) and here the mineral occurs in a limestone close to an igneous contact. A similar occurrence is reported from Virginia (Shannon, 1925). It is believed that the find at Rose Blanche is the first reported Canadian occurrence of type xonotlite.

Xonotlite also occurs in association with ultrabasic bodies (Kaye, 1953; Smith, 1954), and is thought to have formed by alteration of vein calcite (Kaye, 1953). Smith (1954), however, suggested that the xonotlite associated with the Bay of Islands Complex, Newfoundland was formed by circulation of heated solutions along fault contacts. In this latter occurrence the xonotlite is associated with hydrogrossular.

X-Ray Diffraction patterns for xonotlite from Rose Blanche and the Bay of Islands were compared and the d spacings found to be compatible within 0.02Å for all observed peaks. The cell dimensions were calculated (Appleman *et al.*, 1972) and found to be dissimilar, primarily in the a dimension, to the values quoted in A.S.T.M. powder diffraction file (1953, 1960) i.e.,

A.S.T.M.	1953	a = 16.5	b = 7.33	c = 7.04
A.S.T.M.	1960	a = 16.53	b = 7.33	c = 7.04
Present calculation		a = 17.032	b = 7.336	c = 7.056

All these values were obtained from naturally occurring xonotlite. Recently (A.S.T.M. powder diffraction file, 1973) cell dimensions were calculated on synthetic xonotlite.

A.S.T.M.	1973	a = 17.020	b = 7.353	c = 7.004

These values are in accord with the cell dimensions calculated from natural xonotlite from Rose Blanche (type xonotlite) and the Bay of Islands Complex. All A.S.T.M. cards give $\beta = 90°$. The present calculation indicates $\beta = 90° 21'$.

BIBLIOGRAPHY

Appleman, D. E., Evans, H. and Hardwerker, D. 1972. Indexing and Least-Squares Refinement of Powder Diffraction Data. U.S. Geol. Surv. Computer Contribution, No. 20.

A.S.T.M. Powder Diffraction File 3-0568, 1953, Xonotlite

A.S.T.M. Powder Diffraction File 10-488, 1960, Xonotlite

A.S.T.M. Powder Diffraction File, 1973, Xonotlite

Kaye, C. A. 1953. A Xonotlite Occurrence in Puerto Rico. Am. Min., V. 38, pp. 860-862.

Larsen, E. S. 1923. The Identity of Eakleite and Xonotlite. Am. Min., V. 8, pp. 181-182.

Shannon, E. V. 1925. Mineralogy and Petrography of Triassic Limestone Conglomerate Metamorphosed by Intrusive Diabase at Leesburg, Virginia. Proc. U.S. Nat. Min., V. 66, art. 28.

Smith, C. H. 1954. On the Occurrence and Origin of Xonotlite. Am. Min., V. 39, pp. 531-532.

Plate 1

Leucocratic Long Range Gneiss with basic inclusions. West of the Cape Ray Fault

Plate 2

Well banded Port aux Basques Gneiss folded by D2 (basement). Port aux Basques

Plate 3

Migmatitic Gneiss. West of Isle aux Morts

Plate 4

Basic bands in the Reworked Port aux Basques Gneiss boudinaged by the reworking deformations. Reworked Port aux Basques Gneiss. East of Granby Sound

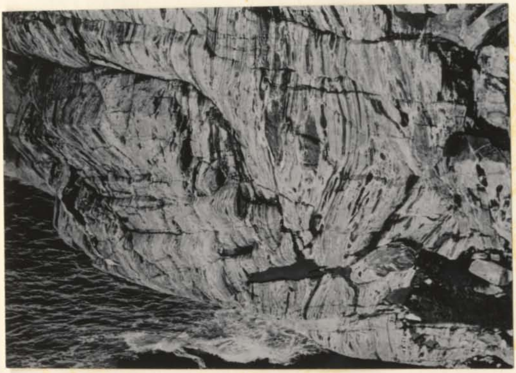


Plate 5

Calc Silicate band in the Reworked Port aux Basques Gneiss boudinaged by the reworking deformations. Reworked Port aux Basques Gneiss. The Barasway

Plate 6

The Diamond Cove Slide east of Harbour le Cou Bay

Plate 7

Square basic Xenolith in the Rose

Blanche Granite. The Barasway

Plate 8

Thin conglomerate bed in the tuffaceous unit. A tectonic

banding is developed axial planar to folds of the

bedding. Windsor Point Group. Windsor Point


D1

Plate 9

Conglomerate? Marking the southwestern extent of the southern sliver of the Harbour le Cou Group.

Rose Blanche

Plate 10

Slump Breccia in fine sand beds.

Bay du Nord Group. Garia Bay

Plate 11

Conglomerate bed in the Bay du Nord Group. Garia Bay

Plate 12

Intrusive contact between the La Poile Batholith

and the Bay du Nord Group. Garia Bay

Plate 13

Staurolite Porphyroblast containing inclusion trails discontinuous with the external schistosity. Two stages of growth i.e., MP1 and MS2. Port aux Basques Gneiss. Grand Bay. X 4

Plate 14

D1 fabric being folded around an F2 fold. The F2 fold subsequently being folded by D3. Port aux Basques Gneiss. Channel Head, Port aux Basques

Plate 15

Intense flattening of the gneissic banding by D3 (basement). Port aux Basques Gneiss. West of Isle aux Morts

Plate 16

D3 incipient boudinage structure plunging at a shallow angle to the northeast. Port aux Basques Gneiss. West of Isle aux Morts

Plate 17

The Harbour le Cou slide, separating basement rocks to the south from cover rocks to the north. North of the Barasway

Plate 18

Crenulation of pre-existing gneissic fabrics by D1 (cover). Reworked Port aux Basques Gneiss, east of Granby Sound


Gneiss


DI (cover)

Plate 19

Micas broken rather than folded around Dl (cover) fold closures. Reworked Port aux Basques Gneiss. East of Granby Sound. X 20 (T.S. 5-74)

Plate 20

Dl (cover) crenulation forming augen around large Porphyroblastic 'Gneissic' garnets. Reworked Port aux Basques Gneiss. East of Granby Sound. X 4 (T.S. 359-72)

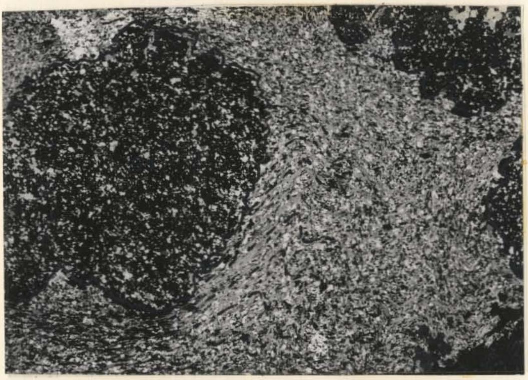


Plate 21

Transposition of gneissic fabric at a D1 (cover) fold core in a quartzo-feldspathic band. Reworked Port aux Basques Gneiss. East of Granby Sound. X 4 (T.S. 302-72)

Plate 22

Garnetiferous Leucocratic Granite Dykes folded and boudinaged by D1 (cover). Reworked Port aux Basques Gneiss. East of Granby Sound

Plate 23

Isoclinal to subisoclinal D1 (cover) folds of the gneissic banding, as shown by a Garnetiferous Leucocratic Granite Dyke. Reworked Port aux Basques Gneiss. West of the Barasway

Plate 24

Micas defining the composite gneissic fabric reorientated parallel to S1. Reworked Port aux Basques Gneiss. West of the Barasway

X 4 (T.S. 9-74)

Plate 25

Garnetiferous Leucocratic Granite Dykes folded by D2 (cover). They contain an earlier fabric in D1 (cover). Cross cutting relationships with the original gneissic banding are obliterated. Reworked Port aux Basques Gneiss. Rose Blanche

Plate 26

D1 (cover) recumbent antiform at White Head. The lower limb of this antiform and associated synform are sheared out northeast along strike and a tectonic slide, the Harbour le Cou slide, developed. Reworked Port aux Basques Gneiss. White Head

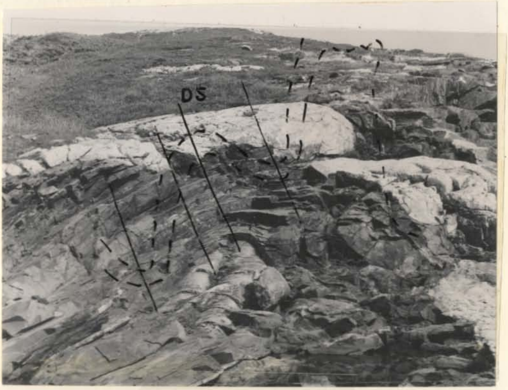

DS

Plate 27

Open F2 fold, folding tight D1 folds of the gneissic banding. Reworked Port aux Basques Gneiss. The Barasway

Plate 28

Inhomogeneous development of D2 (cover). Reworked Port aux Basques Gneiss. Rose Blanche

Plate 29

Subisoclinal D2 (cover) folds outlined by Garnetiferous Leucocratic Granite Dykes. These dykes contain S1. Reworked Port aux Basques Gneiss. East side of Harbour le Cou Bay.

Plate 30

D3 (cover) crenulation of all earlier fabrics. Reworked Port aux Basques Gneiss. North of Mull Face Bay. X 4 (T.S. 446-72)


D3

Plate 31

Relict sedimentary banding? D1 (cover) is poorly developed and parallel to the banding. D2 (cover) folds S1 and the banding. Harbour le Cou Group. North of the Barasway. X 4 (T.S. red)

Plate 32

Sharp compositional banding defined by garnet-biotite rich and Quartz rich bands. This is a bedding and D1 (cover) feature. The bands are tightly refolded by D2 (cover). Harbour le Cou Group. 100 m. west of Rose Blanche Brook

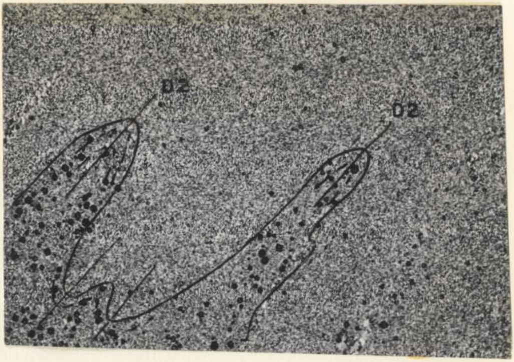

D2
D2

Plate 33

Composite S2 fabric with remnant S1 locally preserved between the schistosity planes. Harbour le Cou Group. East Side of Harbour le Cou Bay. X 10 (T.S. 444-72).

Plate 34

D2 (cover) transposition of S1 resulting in a composite fabric. Harbour le Cou Group. Harbour le Cou. X 4 (T.S. 62-74).


S2

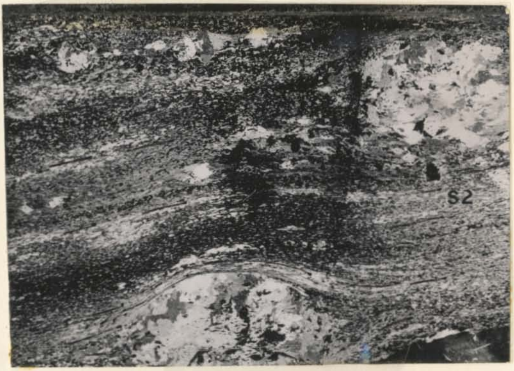

S2

Plate 35

D2 (cover) open folding of the Cape Ray Fault mylonite. Cape Ray Fault Zone. X 4 (T.S. C.R.F.).

Plate 36

Quartz porphyroblasts showing pull apart structures with the cross fractures defined by granulated quartz. Long Range Gneiss. X 20 (T.S. 74).


Si2

Plate 37

Mica fabric developed close to the Cape Ray Fault by breakdown of plagioclase to sericite. Long Range Gneiss. X 4 (T.S. 260)

Plate 38

MP1 staurolite containing straight inclusion trails defined by quartz. Note the MS2 growth with inclusion trails parallel to the external S2. Port aux Basques Gneiss. Port aux Basques. X 20 (T.S. 337)


Sericite

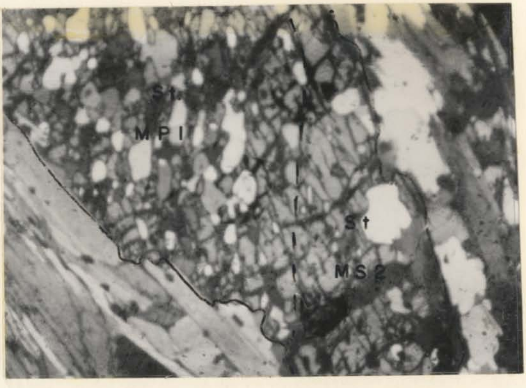

St.
MPI
St
MS2

Plate 39

MS2 acicular kyanite defining, with Mica, the S2 fabric.
Port aux Basques Gneiss. Port aux Basques. X4

Plate 40

MP2 Kyanite containing quartz inclusions which contain staurolite inclusions. Port aux Basques Gneiss. Port aux Basques. X 20.


Ky

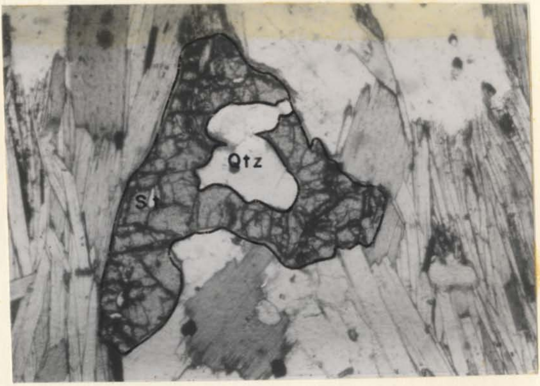

Ky
Qtz
St
St

Plate 41

Recrystallisation of MP1 staurolite resulting in a coarse staurolite-quartz intergrowth, around which S2 forms augen. Port aux Basques Gneiss. Port aux Basques. X 15

Plate 42

Sillimanite and kyanite Co-existing Port aux Basques Gneiss. Port aux Basques. X 50


Qtz
St

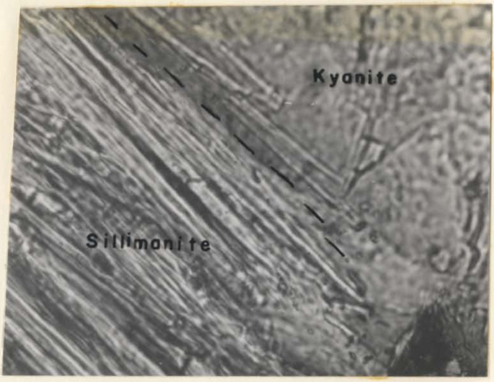

Sillimanite
Kyanite

Plate 43

Kyanite altering to sillimanite. Port aux Basques Gneiss. Port aux Basques. X 60

Plate 44

MS2-MP2 Kyanite folded around F3 folds and subsequently polygonised. Port aux Basques Gneiss. Port aux Basques. X 12


Kyanite
Sillimanite

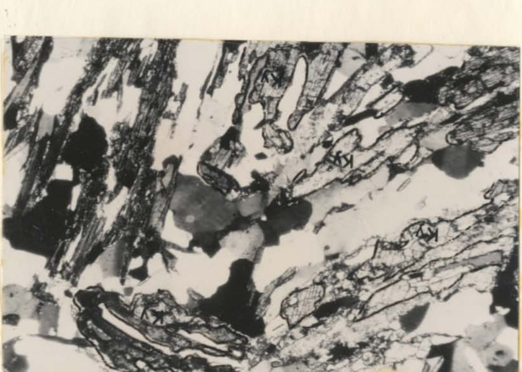


Plate 45

MP3 growth of garnet in fine garnet-quartz bands.

Port aux Basques Gneiss. Port aux Basques. X 8

Plate 46

Relict gneissic banding in the migmatites at

Foxroost. Port aux Basques Gneiss. Foxroost.

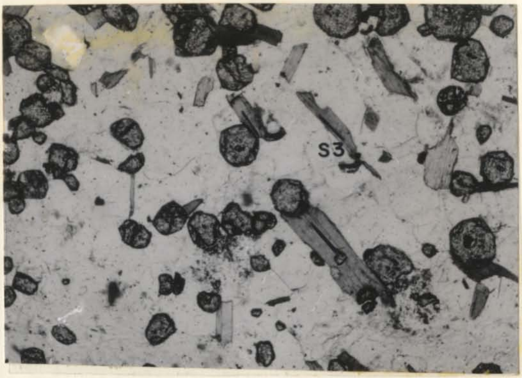
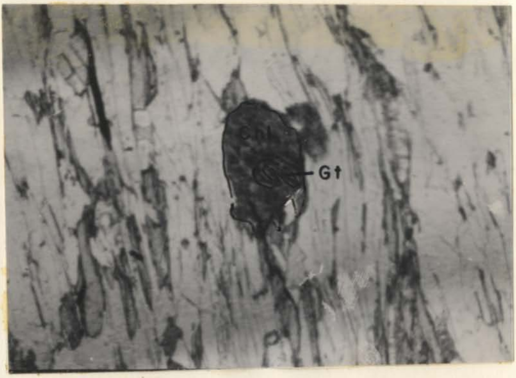

S3

Plate 47

Breakdown of garnet to chlorite at the margins of the shear zones. The euhedral outline of the garnets is still preserved. Reworked Port aux Basques Gneiss. Isle aux Morts. X 15 (T.S. 356)

Plate 48

Development of MS1 muscovite porphyroblasts which are in part augened by S1 and also help define that fabric. This growth is a regrowth of 'Gneissic' micas rather than the nucleation and growth of a new phase. Reworked Port aux Basques Gneiss. Shear Zone at Isle aux Morts. X 4 (T.S. 136-72).


Chl
Gt

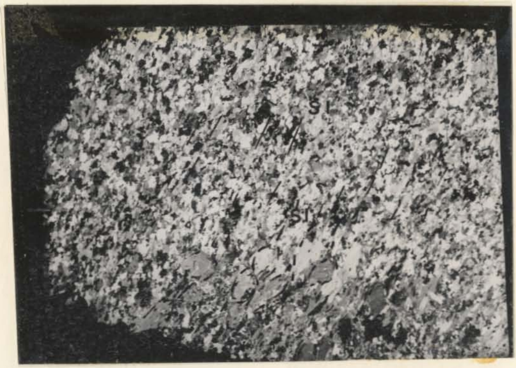

Sl
Sl

Plate 49

Regrowth of gneissic garnets along quartz boundaries. Reworked Port aux Basques Gneiss. Shear zone at Isle aux Morts. X 12 (T.S. 136-72).

Plage 50

MS1 fibrolite occurring in elongate pods defines S1. The garnets here show little tendency to be broken down although some contain biotite 'inclusions'. Reworked Port aux Basques Gneiss. Shear zone at Isle aux Morts. X 4 (T.S. 125-72).


Gt
Gt
Gt

Plate 51

Towards the centre of the shear zone sillimanite becomes better developed and garnet and tourmaline have nucleated and grown as new mineral phases. Reworked Port aux Basques Gneiss. Isle aux Morts. X 4 (T.S. 148-72)

Plate 52

Nucleation and growth of MS1-MP1 garnet throughout the entire rock. Reworked Port aux Basques Gneiss. Isle aux Morts. X 4 (T.S. 22)

Plate 53

Optical continuity of white mica porphyroblasts associated with sillimanite. Reworked Port aux Basques Gneiss. Isle aux Morts. X 25 (T.S. 22)

Plate 54

White mica filling transverse fractures in a fibrolite pod and occurring as torpedo shaped lenses parallel to the length of the fibrolite needles. Reworked Port aux Basques Gneiss. Isle aux Morts. X 50 (T.S. 148-73).


Sill
White
Mica

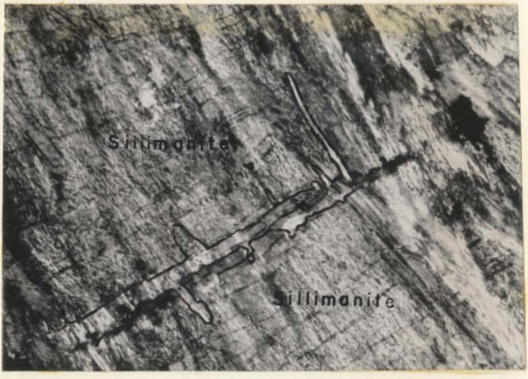

Sillimanite
Sillimanite

Plate 55

Selective alteration? of fibrolite at the ends rather than along the long axis of a fibrolite pod. Reworked Port aux Basques Gneiss. Isle aux Morts. X 25 (T.S. 148-73).

Plate 56

Large white mica porphyroblasts containing rosettes of fibrolite. Reworked Port aux Basques Gneiss. Isle aux Morts. X 15 (T.S. 22)


Sill
Musc

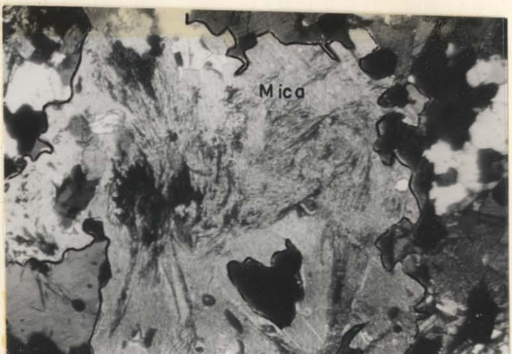

Mica

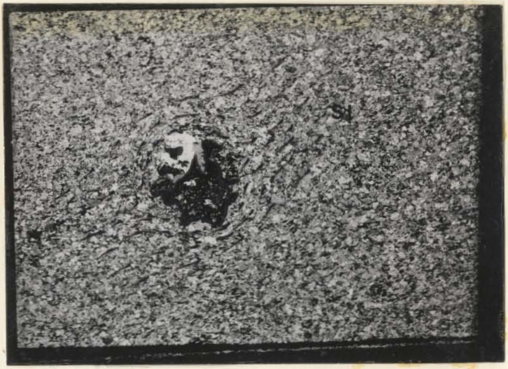
Plate 57

S1 biotite forming augen around remnant gneissic porphyroblasts. Biotite 'inclusions' are present in the garnets. Reworked Port aux Basques Gneiss. East of Granby Sound. X 4 (T.S. 263-72).

Plate 58

Remnant gneissic garnets with embayed rims and biotite developed around these rims. This is a D1 (cover) effect. Reworked Port aux Basques Gneiss. East of Granby Sound.

X 4 (T.S. 5-74).



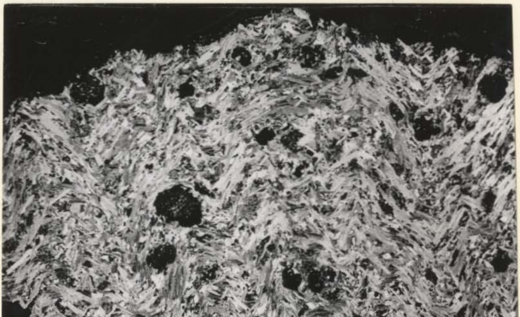
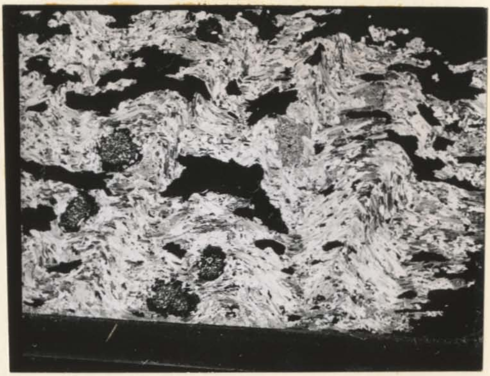


Plate 59

Pronounced embayment of remnant 'Gneissic' garnets. This destroys the original euhedral outline of the garnets. Reworked Port aux Basques Gneiss. East of Granby Sound. X 4 (T.S. 360).

Plate 60

Nucleation and growth of tourmaline on 'Gneissic' micas. Reworked Port aux Basques Gneiss. East of Granby Sound. X 40 (T.S. 360).



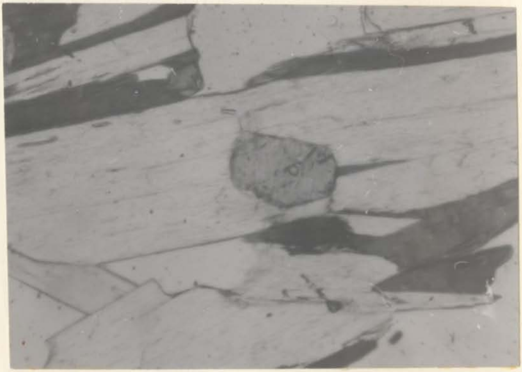


Plate 61

Regrowth of 'Gneissic' garnet along grain boundaries. This growth has a dendritic habit and cross cuts the gneissic fabric. Reworked Port aux Basques Gneiss, East of Granby Sound. X 20 (T.S. 360).

Plate 62

Dendritic habit of garnet parallel to S1 (cover). Reworked Port aux Basques Gneiss. The Barasway. X 25 (T.S. 302).


Sl
Gt

Plate 63

Nucleation of a new garnet phase at mica-mica grain boundaries. Reworked Port aux Basques Gneiss. The Barasway. X 60 (T.S. 300-72)

Plate 64

Garnet with inclusion free core surrounded by an inclusion rich rim, surrounded by an inclusion free rim. Reworked Port aux Basques Gneiss. Diamond Cove. X 15 (T.S. 237-73)

Plate 65

Garnets with star shaped inclusion filled areas surrounded by an inclusion free rim. Reworked Port aux Basques Gneiss. Bay le Moine. X 12 (T.S. 74-74)

Plate 66

Breakdown of Composite S1-S2 fabric at an F3 fold hinge. Reworked Port aux Basques Gneiss. Diamond Cove. X4 (T.S. 237-73).

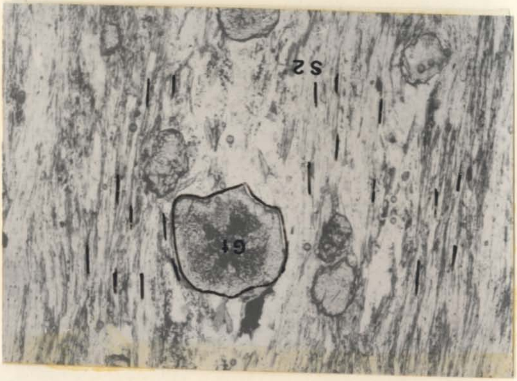
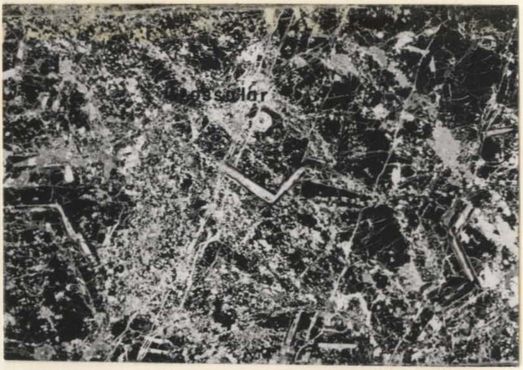

S2
G1

Plate 67

Cyclic growth of grossular with zoisite and calcite. Calc silicate band in the Reworked Port aux Basques Gneiss. The Barasway. X 4 (T.S. 1st).

Plate 68

MSl fibrolite in association with biotite. Harbour le Cou Slide. Harbour le Cou. X 15 (T.S. 62-74).




SI
SI

Plate 69

MP1 garnets with star shaped inclusion filled areas surrounded by inclusion free rims. Harbour le Cou Group. North of the Barasway. X 12 (T.S. Sed)

Plate 70

MP1 Garnets with straight inclusion trails defined by quartz and feldspar. Harbour le Cou Group. West of Rose Blanche Brook. X 15 (T.S. 400).

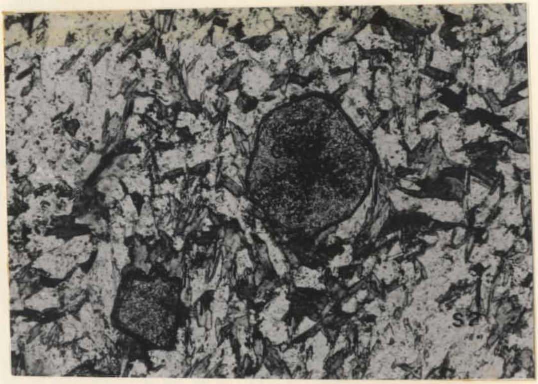
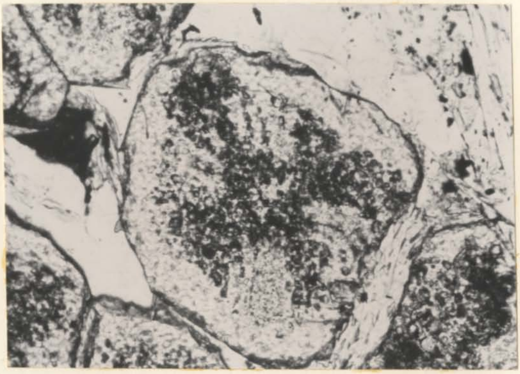

S2

Plate 71

MP1 garnets with inclusion rich cores. These inclusions define various shapes including six and four pointed stars and double ended Ys. The cores are surrounded by an inclusion free rim. Harbour le Cou Group. East side of Harbour le Cou Bay. X 35 (T.S. 444-72).

Plate 72

Cordierite porphyroblast related to thermal metamorphism by the Petites Granite. These crystals show well developed lamellar twinning. Bay du Nord Group. Little Garia Bay. X 4 (T.S. 315-73A)




c
c
c
c
S2

Plate 73

Andalusite porphyroblasts related to thermal metamorphism by the Petites Granite. These contain straight inclusion trails (D1 cover)). The D2 (cover) fabric forms augen around these crystals. The slight alteration at the rims is related to D2 (cover). Bay du Nord Group. Little Garia Bay.

X4, X20 (T.S. 307)


S2

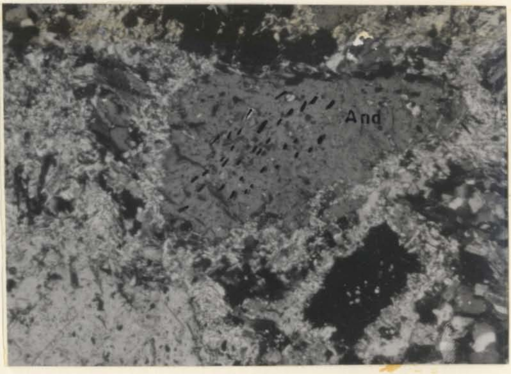
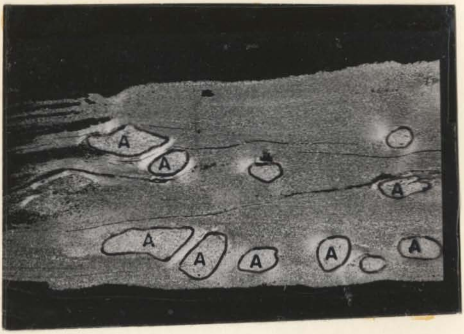

And

Plate 74

Andalusite? porphyroblasts completely altered to sericite. S2 forms augen around these crystals. Bay du Nord Group. Garia Bay. X 4 (T.S. 371).

Plate 75

Garnet with rounded 'turbid' core and inclusion free rim. The growth of the rim is related to thermal metamorphism by the Petites Granite. The rounded nature of the turbid core indicates a possible sedimentary origin. Bay du Nord Group. Little Garia Bay. X 30 (T.S. 458).


A
A
A
A
A
A
A
A
A


Gt

Plate 76

Garnet included in Actinolite. The actinolite is related to thermal metamorphism by the Petites Granite. These garnets are not surrounded by an inclusion free rim. Bay du Nord Group. Garia Bay. X 20 (T.S. 458)

Plate 77

MP1 garnet growth. Inclusions of quartz and feldspar are confined to ~~the central part~~ of the crystals and crudely define straight trails. This is surrounded by an inclusion free rim. The S2 fabric forms augen around these crystals. Bay du Nord Group. Bay le Moine. X 40 (T.S. 454-72)


Act
Gt

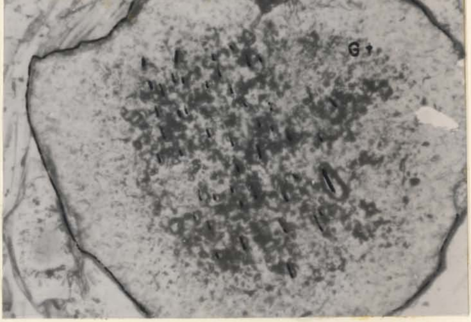
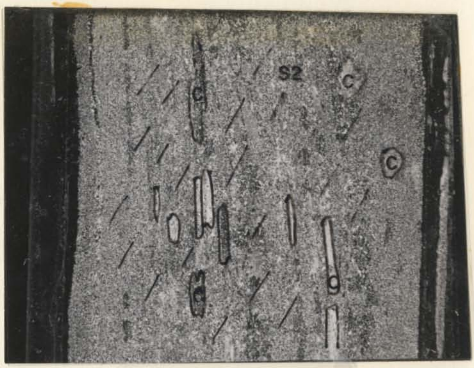

Gt

Plate 78

MP2 cordierite overgrowing the D2 (cover) fabric. Bay du Nord Group. Little Garia Bay. X 4 (T.S. 315-73)

Plate 79

MS1 muscovite being folded by D2 (cover). The D2 fabric shows a strain slip relationship to S1 Windsor Point Group. Windsor Point. X 15 (T.S. 758)


S2
C
C
C
C
g

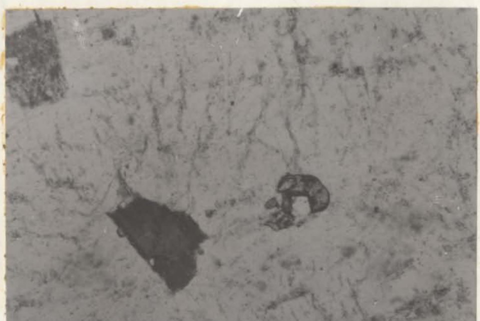

S2

Plate 80

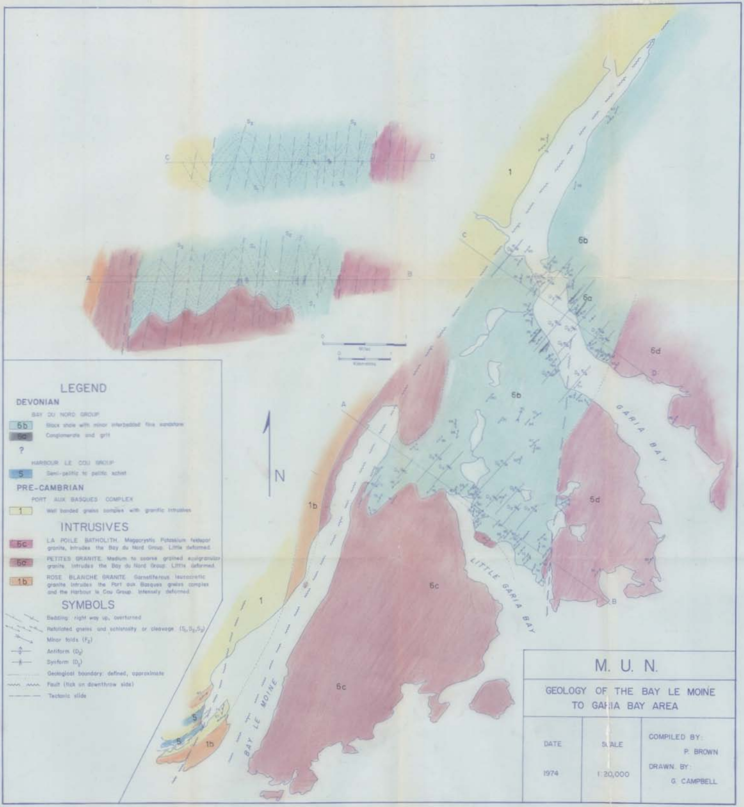
Concentration of euhedral to subhedral inclusion free garnets in a late leucocratic dyke. Rose Blanche Granite. Rose Blanche. X 15

Plate 81

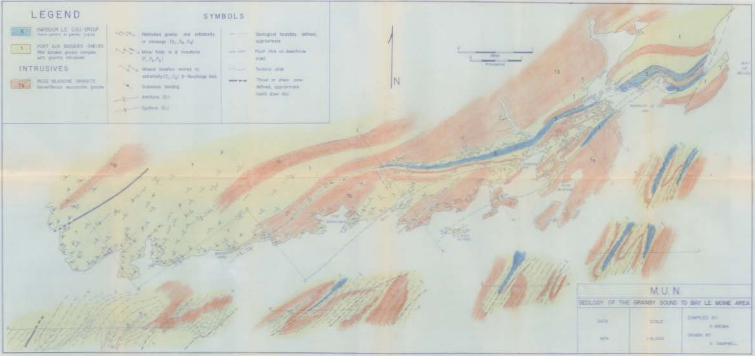
Inclusion free igneous garnet included in a potassium feldspar crystal. Rose Blanche Granite. Granby Sound. X 30



LEGEND
DEVONIAN
PRE-CAMBRIAN
INTRUSIVES
DEVONIAN
PRE-CAMBRIAN
SYMBOLS
N
MUN
GEOLOGY OF THE PORT AUX BASQUES
TO GARIA BAY AREA,
SOUTHWEST NEWFOUNDLAND
DATE
SCALE
COMPILED BY
DRAWN BY



LEGEND
DEVONIAN
BAY DU NORD GROUP
6b
Black shale with minor interbedded fine sandstone
Conglomerate and grit
?
HARBOUR LE COU GROUP
5
Semi-pelitic to pelitic schist
PRE-CAMBRIAN
PORT AUX BASQUES COMPLEX
1
Well banded gneiss complex with granitic intrusives
INTRUSIVES
6c
LA POILE BATHOLITH. Megacrystic Potassium feldspar granite, intrudes the Bay du Nord Group. Little deformed.
PETITES GRANITE. Medium to coarse grained equigranular granite. Intrudes the Bay du Nord Group. Little deformed.
1b
ROSE BLANCHE GRANITE. Garnetiferous leucocratic granite. Intrudes the Port aux Basques gneiss complex and the Harbour le Cou Group. Intensely deformed.
SYMBOLS
Bedding: right way up, overturned
Refoliated gneiss and schistosity or cleavage (S_1, S_2, S_3)
Minor folds (F_2)
Antiform (D_2)
Synform (D_2)
Geological boundary: defined, approximate
Fault (tick on downthrow side)
Tectonic slide
N
GARIA BAY
LITTLE GARIA BAY
BAY LE MOINE
M. U. N.
GEOLOGY OF THE BAY LE MOINE TO GARIA BAY AREA
DATE
1974
SCALE
1:20,000
COMPILED BY:
P. BROWN
DRAWN BY:
G. CAMPBELL


LEGEND
HARBOUR LE COU GROUP
PORT AUX BASQUES GNEISS
INTRUSIVES
ROSE BLANCHE GRANITE
SYMBOLS
N
M.U.N.
GEOLOGY OF THE GRANBY SOUND TO BAY LE MOINE AREA
DATE
SCALE
COMPILED BY
DRAWN BY